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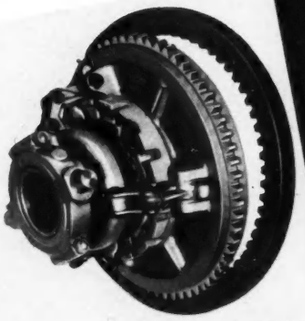

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ENGINEERING

An Illustrated Weekly Journal

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EXAMINATIONS

With the approach of the examination season in the universities and technical colleges it is timely to consider the present system of examining in engineering. In this country it is the practice for students to attend courses of lectures and carry out laboratory work in selected subjects and then to submit themselves to written examinations on these subjects. The examiner, who in many cases may also be their teacher, is faced with two main alternatives. Should he seek to find out what they know, or what they do not know?

From the students' point of view the former is by far the most popular method since they quickly realise that, provided the course has been conscientiously followed, the examination questions will at least be similar to those which have been given for practice during the year. The student may even specialise in solving certain types of question and bank on those particular topics turning up. Indeed he has many aids to his endeavours, for in the past year or two numerous books giving the classified and worked solutions of typical examination questions have been published. But is this the object of the teacher? Has the student been given a good engineering education if his energies are directed to such an end? Surely not, for it must be an object of any educational system to present certain fundamental facts and then to teach the art of reasoning as applied to given departments of knowledge—that is, to teach logic—to teach the man to be able to think clearly for himself. Fortunately the fundamental facts are few in number so that their numerous applications can be made an exercise in logic.

This aim may be achieved by examinations which set out to present problems that are even quite impractical and academic, but which require sound fundamental knowledge of principles for their solution. Too many examination questions in engineering attempt to camouflage the essentials behind a barrage of technical terms. It may be claimed that this is good practice at sifting information and appreciating the jargon, but is the examination the time to practice it? Perhaps asking fewer questions each having several aspects for consideration would be a solution. Thus the examination paper which starts with the rubric—"Answers are expected to a few questions"—and then gives a number of meaty questions, possibly on quite obscure topics, is surely the right approach. In the limit, setting the candidate a design problem might be a better test of the ability and promise of the potential engineer.

The future employer of an engineering student, although he would like a man with specialist knowledge, usually faces up to the task of providing the necessary specialist training. He is far more concerned that the man shall know how to learn and be able to make an intelligent appreciation of a problem and propose methods of solving it, rather than be able to manipulate certain formulae relating to the performance of engines or machines with which he is not even concerned.

Whether a design question is a practical method of examining, however, is questionable. Assessing the value of solutions is difficult even when there is only one correct solution with a series of well-defined intermediate steps. It is to be noted though that assessments made on general appearance and clarity of expression often differ but little from those made by the most meticulous step-by-step marking. The method of examining by means of a design would seem to be most applicable to the final-year examinations, which should be planned to show if the student is able to apply the facts and scientific methods that have been demonstrated to him during the several years of his course. The assessment of such an examination would have to be made on the basis of an intelligent attempt rather than on a correct solution. Intermediate examinations, which are really progress reports, are perhaps best carried out on the "what do you know" principle. The trend in universities to-day is to provide laboratory problems which can be carried out in a manner determined by the student after reflection and consultation with the demonstrator, rather than to give well-worked experiments in which all that is required is the careful following of an instruction sheet. The same trend could also apply to written problems if examiners concentrated on design questions in which the method of approach does not follow a well beaten track.

Ideally, then, the examiner should set out to find what the student does not know rather than what he does know. This may be done by asking design questions which involve an unfamiliar application of principles, rather than by asking questions which are almost exactly on work described in lectures. The "what do you know" examination is really a memory test. The "what don't you know" examination separates the sheep from the goats—usually rather drastically. There are careers for both sheep and goats, but at least let us have an examination assessment which differentiates between those suited to original research and development and those who will best serve and maintain existing engineering practices.

Weekly Survey

Cover Picture : *Although the piping of gases directly from maker to user is likely to become increasingly common, the use of seamless steel cylinders for storing and transporting smaller quantities of gas will continue to be essential. The front cover shows a stage in the manufacture of an oxygen cylinder; a billet has been pierced on a vertical punch press and is being de-scaled prior to further working.*

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PROSPEROUS TIMES

British engineering is prosperous as never before: order books are full, capacity is being extended, most materials are freely available and productivity is rising. In such fair weather one is tempted to look for clouds in assessing the prospects during the next few years, and if one looks hard enough a good many can be seen although they may pass with ill-effects.

The biggest, without doubt, is the growing deficit on external trade, but there is also the shortage of labour threatening industrial growth, and the growth of foreign competition—a threat made more real by the international pressure to liberalise trade and currency through GATT, the International Monetary Fund and other organisations strongly backed by the U.S. Government. There might well be a major balance of payments crisis later this year. The engineering industries are fast becoming the major source of foreign currency, as the country's staple industries are increasingly being excluded from major markets by local manufacture. This is also true, of course, of some engineering products—and not all of them old—for example, motor-cars are being made locally in some of the largest markets.

The last article in the Engineering Outlook series on page 397 discusses these problems. Some important questions come to mind: do we know very much about the meaning of capital investment measured in £ *s. d.*? From the national point of view much can be wasted on, say, new machines to produce goods which cannot assist our industrial growth or bring in the foreign exchange needed to pay for our imports, or machines unnecessarily expensive in relation to the cost of labour. In many cases—but perhaps not in enough—" technical progress can enable a higher volume of output to be achieved for a considerably lesser investment in monetary terms than was formerly required." Higher machine utilisation could vastly increase productivity and there is certainly much room for improvement in that direction.

At present the relationship of the value of investment per worker and the cost of labour is such that there is often doubt as to the correct policy: expensive special machines fitted with varying degrees of automatic controls or general-purpose machines and skilled men to work them. The shortage of labour is likely to exert pressure in the direction of high mechanisation. Care will be needed to define which exports should be expanded; obviously at the present time products with a low British labour content, or a high imported raw-material content, in their price tend to worsen rather than improve the country's prospects to balance its external trade.

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AUSTRALIA THROTTLES IMPORTS

The Australian imposition of restrictions of 15 per cent. on imports of goods classified as " essential " and 33⅓ per cent. on most others is expected to save about £A100 million in 1955-56 and £A160 million a year when fully effective. British manufacturers of cars, electric household appliances and textiles are likely to be the chief sufferers, although the effects of such a decision in the main British market will be widely felt throughout industry. Imports of British cars last year totalled 121,000, most of them CKD (completely knocked down), and although they qualify for the lighter 15 per cent. cut, shipments may be reduced by 18,000 cars over 12 months.

This is the second time in four years that the Australian Government have found it necessary to apply severe restrictions on imports. In 1952 there was an almost complete economic collapse caused by a deficit on external trade; in 1954 severe falls took place in receipts from wool exports, mainly owing to lower prices as well as falls in exports of wheat, meat and dairy products. The necessity for the restriction of imports can hardly be questioned: last June, at the beginning of the current financial year, the Commonwealth Bank of Australia held gold and foreign balances worth £A525 million; by the end of February these balances had fallen to £A405 million, a fall of 23 per cent. in eight months.

The future is hard to predict. The main cause of the trade deficit is undoubtedly excessive importing, which, in turn, arises from a standard of living (particularly in secondary industry) higher than the country can support with its major export industries—wool, meat and dairy products. The situation could be transformed by a discovery of major oil resources but this is little nearer now than a year ago and may never come. The obvious remedy would be to expand exports of primary industries by devoting more of the country's resources to their development. Such a course inevitably raises the difficult question of the relative prosperity of agricultural and manufacturing workers; the strength of manufacturing trades unions makes this course somewhat unlikely. The recovery in commodity prices may restore Australia's capacity to remove import restrictions at a fairly early date, but the need to stabilise the situation is such that the removal of quotas is unlikely to become practicable for one or two years at least. British manufacturers must therefore look elsewhere for increased exports despite Sir Arthur Fadden's assurance that " the Government remains firm in its intention to reduce and finally eliminate all import restrictions as soon as this can safely be done."

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CLARKE, CHAPMAN & CO.

A few years ago the slow rate of installation of water-tube boilers was blamed, at least partly, for delays in the power-house construction programme of the British Electricity Authority, and manufacturers were blamed for their failure to expand capacity rapidly enough. The recent report of one manufacturer, Clarke, Chapman and Company, however, shows that there can be little criticism of the way in which the industry has responded to B.E.A.'s needs. A new fabricating shop completed towards the end of 1953 enabled the company to increase their output considerably in 1954; capacity will be further extended this year by the addition of another 80-ft. bay. The company have so far commissioned plant having a total capacity of 2½ million lb. of steam per hour. This includes the first of nine boilers for Stella generating station, the speed of erection of which was highly commended by B.E.A.

Clarke, Chapman and Company are also fortunate in that demand for all their products is at a very high level. Output of their marine department, which specialises in the manufacture of both electric and steam deck auxiliaries, was at a record level in 1954. In particular, output of the company's splash-lubricated steam winch had to be increased by 25 per cent. A new electrical winch giving controlled lowering which eliminates the need for a foot-brake has been developed, and progress is being made with the development of alternating-current equipment. The company's mechanical-handling department has also been increasing output, which includes skip hoists for blast furnaces and conveyors for parcel distribution on British Railways. An associated company, the Moxey Conveyor and Transporter Company, have built new capacity at West Bromwich, which is now in full production on orders including installations for steelworks and power stations. Export business is being developed concurrently with that at home. The company have established a Canadian office and are to exhibit at the Toronto Fair; they should do a considerable volume of business in Canada. The greatest uncertainty is in Continental markets, but the company's outlay on re-tooling and generally raising productivity has been of great assistance in maintaining orders against severe competition.

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MERCHANDISE CHARGES BY RAIL

The railway freight charges scheme issued last week after consultation with representative bodies of railway users breaks new ground. The scheme has been submitted to the Transport Tribunal in accordance with the Transport Act, 1947 and the Transport Act, 1953. It deals with charges and conditions of carriage for merchandise and livestock against the economic background provided by the Transport Act of 1953, which had among its objectives the creation of circumstances which would improve the competitive power of the railways against road transport.

The existing system of charges is based on the principle of averaging costs over all traffic. This necessarily involves cross-subsidisation between routes and types of customer. It was elaborated to give the railways a standard revenue under conditions of near-monopoly. The proposed scheme is based on different principles. It is mainly a scheme for maximum charges, and in fact 85 per cent. of the traffics affected by it still come under these maxima arrangements. The two factors fixing maximum charges are to be weight and " loadability." By means of this second factor, the maximum charge appropriate to any consignment can be determined. The Commission emphasises that within the new maximum charges they will be able to pursue a policy of rate-making to encourage traffic in wagon-load consignments. The scale of charges reflects comparative costs and gives a pronounced taper in the charge per mile as the mileage increases. This new advantage on long-distance hauls is clearly aimed at competition with independent road hauliers, and should give the railways an advantage with the type of hauls that they can operate most efficiently. The scheme is intended to provide a new structure, but the Commission assert that it is not an object of the scheme to bring about a general increase in charges to meet higher costs. If the scheme is approved by the Tribunal the Commission hope to make the change-over gradually after continued consultation with representative bodies of traders.

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DIRECT-CURRENT TESTING OF STATOR WINDINGS

As is only right and proper, differences of opinion on technical practice exist in engineering circles. It is seldom, however, that these differences are so clear cut as those disclosed in the paper by Mr. R. T. Rushall and Mr. J. S. Simons, of which we gave an account on page 369 of our last issue. In this the authors suggested that the high-voltage direct-current tests which had been introduced in America to establish the insulation quality of large stator windings non-destructively were not valid for the purpose and, in fact, led to no real judgment of electric strength.

This categorical opinion was almost unanimously supported by the speakers who took part in the discussion at the Institution of Electrical Engineers on Wednesday, March 16. One contributor, indeed, went so far as to express his amazement that the Americans had obtained positive results by this method, while both he and another speaker were of opinion that direct-current testing was of no value in proving the " goodness " of insulation and that no useful predictions could be made from the results.

Non-destructive tests of the insulation of such an expensive piece of equipment as the stator of a large alternator are, of course, worth some

pairs to discover. It is essential, however, that such methods should disclose any weaknesses and, what is almost the same thing, that the test results should guarantee subsequent serviceability. As it is, direct-current testing does not appear to fulfil this specification and even gives different results on two machines of the same construction. The interesting suggestion was made that direct-current testing might be suitable for extremely old machines, but invalid for new ones.

* * *

HEALTH AND WELFARE

The industrial museum of the Factory Department of the Ministry of Labour was formally renamed the Industrial Health and Welfare Centre by the Minister, Sir Walter Monckton, on March 22. The Centre, now more aptly named, is a permanent exhibition of methods, arrangements and appliances for promoting safety, health and welfare in industry.

In the safety sections, methods of accident prevention are demonstrated, and there are numerous machines from different industries with various types of safety guards. Exhibits show the principles of fencing dangerous machinery by fixed guards, interlocking devices, sweep-away guards and instantaneous step mechanisms. In the electrical section are methods of testing on high and low tension, types of wiring, a demonstration of some dangers of screw-cap lampholders, and different types of switches and fuse boxes and special lighting fittings for dusty and dangerous atmospheres.

In the health sections can be seen the effects of certain industrial diseases, and the steps which must be taken to prevent or cure them. Protective devices for injurious processes are shown, including some for use when people are entering places almost certain to be very dangerous—confined spaces where explosions are likely due to faults or accidents.

The Centre is full of interesting ideas and demonstrations, and many will realise with horror what might easily happen in their own factories when they see the ways accidents can be caused. Measures to prevent such happenings can be part of an enlightened policy of ordering conditions so that everyone can give of his best. The Centre is at 97 Horseferry-road, London, S.W.1. Guides show visitors round and visits by parties can be arranged in advance.

* * *

STEEL MISSION FOR INDIA

Indian plans for industrial development have certainly not lacked boldness, and perhaps the most ambitious of all are those for expanding output of iron and steel. Under the first five-year programme, output of steel is scheduled to reach 2·25 million tons per annum by 1958 compared with 1·47 million tons in 1953. According to Mr. K. C. Reddy, Minister of Production, 6 million tons are planned under a second programme and 10 million tons under a third. Mr. B. M. Birla, President of the Indian Federation of Chambers of Commerce, has even suggested that 20 million tons should be achieved by 1966.

The enthusiasm of the builders of the new India has already produced remarkable results and the targets set cannot be too lightly dismissed as unrealistic. The technical and financial resources of India are limited, but help has been forthcoming from the Western nations—and also from Soviet Russia. British capital and technicians have already helped to establish important new engineering industries, and it is now reported that an official British mission is to leave for India on April 2 under the Technical Co-operation Scheme of the Colombo Plan to advise on the establishment of a new steelworks. The departure of this mission, which is headed by Sir Eric Coates and includes representatives of leading British manufacturers of iron and steel-making plant, follows after months of private and Government negotiation. The basis was the offer by the Metallurgical Export Company, representing six plant manufacturers, to build a plant of about 1,000,000-tons capacity and costing about £70 million, but more concrete proposals will emerge from the report of the mission who are to make a detailed study.

The proposed British-built plant is only one of several in the Indian programme. An agreement was signed with the Russians at the beginning of February for another plant of 1,000,000 tons capacity. Under this the Russians have nine months to present a detailed project report, and to settle a definite price. The Russian terms as set out in the original broad proposal seem to have been exceptionally generous: the total cost of the scheme was estimated at £62 million and payment was to be spread over 15 years at 2½ per cent. interest. A contract for a plant of 500,000 tons went to the German Krupps-Demag combine in 1953, and it was recently announced that this plant is to be increased to 1,000,000 tons capacity. Capacity of the Tata Iron and Steel Company is to be expanded by 500,000-tons, and the Indian Government are considering the erection of a plant of 500,000-tons capacity in South India. The execution of these five schemes should thus bring Indian capacity to within 500,000 tons of the target of 6 million tons under the second five-year programme.

* * *

TORSIONAL VIBRATIONS IN MARINE TRANSMISSIONS

One of the subjects to be discussed by the Institution of Mechanical Engineers at their meeting to-day, April 1, is " The Prediction and Measurement of Vibration in Marine Geared-Shaft Systems." It is now mandatory for marine engine builders to submit to Lloyd's Register of Shipping calculations of expected torsional vibration characteristics of transmission systems from all internal-combustion engines and from turbine units located aft, of vessels intended for classification ; such calculations can be quite laborious by conventional methods. The author of the above paper, the late Mr. H. G. Yates, has presented the results of some eight years of investigation on the topic.

We publish in this issue a further article (which we have had in our hands for some time) on the same topic by Mr. J. P. Duncan. The fact that this work was pursued quite independently of Mr. Yates argues the need and shows the advantages of applying well-known mathematical and electrical techniques to the solution of mechanical problems of this nature. Although well known, these techniques are not as widely practised as they might be.

Most tedious calculations are now handled on computers or analogues. Mr. Duncan's article shows how a particular problem requiring much labour by conventional methods can be solved by the automatic adjustment of currents and voltages in an electrical circuit.

As with so many engineering problems, a mathematical prediction only provides a realistic answer when based on accurate data. This can be obtained by continued experiments on large installations of this type. It can only be hoped that builders in a position to do so will undertake such work.

* * *

TECHNICAL DISCIPLINE FOR THE ARTS STUDENTS?

This country has only 64,000 scientists and needs 90,000. These figures were given by Dr. A. Fleck, chairman of Imperial Chemical Industries when speaking recently at the opening of the Plymouth and Devonport Technical College. Three types of leader are needed on the production side in British industry, said Dr. Fleck—scientists, technologists and technicians, along with a large body of skilled craftsmen. Britain's greatest shortage lay in technologists since the exploitation of existing knowledge was at least as important as the discovery of fresh knowledge. His differentiation between the scientist and the technologist was in fact the familiar distinction between the pure and applied scientist. He went on to say that there was great need of people with powers of leadership combined with scientific background, and that he would like to see more people who were studying the arts and humanities adding the sciences to their studies.

Dr. Fleck's views on these subjects are of more than usual significance since he is the active chairman of probably the largest group of technologists organised for commercial purposes in the country. I.C.I's experience is pre-eminently with chemists and chemical engineers, but that company's experience has lessons for all concerns which draw their expertise from men trained in the natural sciences. It is also of interest to note that other contributions on the subject of technological and scientific training have recently been made by representatives of chemical industry. They were speaking at the international conference on " The Function and Education of the Chemical Engineer in Europe."

The opinion of Dr. Fleck on the importance of applied technology as opposed to pure research (which, in this country unlike in the United States, has always attracted more prestige than applied work) has been stated on many previous occasions by other eminent men. His insistence, however, that arts graduates should be given some of the technical discipline of the sciences is a point which will repay further thought. It is often said that the scientist should be equipped with some knowledge of the humanities in order to avoid the dangers of his own specialism; it is refreshing to hear it said with authority that those trained in the arts faculties would be better equipped for industry if they were given some systematic education in the sciences.

* * *

RIVAL CLAIMS OF TEACHING AND INDUSTRY

The Government are reported to be reviewing the whole question of scientists in the public service to ensure that the most economic use is made of them. Recently the Minister of Education, Sir David Eccles, told the House that he had approved the Burnham Committee's proposals that increased allowances be paid to teachers doing advanced work in schools, and he considered that careers prospects for such teachers would consequently be much improved.

On the same occasion he reported that the Federation of British Industries were asking their members to refrain from raising salaries in competition with the Burnham proposals, and to review the use made of science graduates. In their letter to member firms and associations, the F.B.I. referred to discussions with the Government on the subject, in which it was pointed out that a hopeless situation would arise if the increased remuneration for teachers were countered by a corresponding raising of salary levels by industry. The Government hoped that industry would not allow this to occur. A neat comment on these recommendations was provided by Mr. George Wansbrough, who in a letter to *The Times* wrote:

" The natural increase in price of that which is in short supply tends to increase the supply and cure the shortage. Has this piece of elementary economic knowledge been withheld from the learning of the pundits in the Ministry of Education? Have the tycoons of the F.B.I. never observed this common fact of the market place? "

Perhaps it might be observed in reply that the price system is not the universal panacea it was once believed to be. Its success depends upon individuals recognising their own true interests, and it is the function of such organisations as the F.B.I. to help us determine what our interests truly are. The benefits of the new proposals are not for immediate reaping, since it takes often as long as ten years to train a technologist; in the market place, however, immediate bargains alone tend to be considered.

MACHINE TOOL TRADES ASSOCIATION

Annual Dinner

Speaking at the annual dinner of the Machine Tool Trades Association in London on March 23, Sir Rowland Smith, chairman of the Ford Motor Company, said he did not think we would see, for a long time, any of the huge American-type automatic machines in Britain. The heavy capital cost meant that, except where there was a great volume of work going through the plant, it would not be possible to amortise it in the necessary time. We had to be careful not to be led away by undue enthusiasm; it was the wise man who thought of the house-keeping and made that the arbiter of what he bought.

Referring to hydraulically-operated feeds on machine tools, Sir Rowland reported that an American to whom he had been talking, and who had "the biggest machine shop in the world," was alarmed by the oil losses and prophesied a return to the screw feed and cam units.

"Although you are producing at very competitive prices," he continued, "there is no doubt that Germany is going to give you as much to think about as it is giving us at the present time. Your order books are full, but we are watching our markets being invaded one by one and I am afraid that is simply the forerunner of what will happen to the machine tool trade. I do not think that it need cause any alarm in your case. I think that you can hold your own with any machine-tool producing country, but see that you get to work now on it before the rot starts." He congratulated British machine-tool makers on the standard of finish of their products, which was comparable with that produced by the best Swiss manufacturers.

Viscount Chandos, chairman of Associated Electrical Industries, remarked that the machine-tool industry, if it was not careful, would have solved the production problem without having "considered what you will do with the idle hands which, I seem to remember in my youth, the devil found some use for."

The chair at the dinner was taken by the retiring President of the Association, Mr. R. D. G. Ryder. The President for 1955–56 is Mr. H. P. Potts, of the B.S.A. Group; the Vice-President is Mr. J. C. Robinson, of Thomas Robinson & Son, Ltd.; and the honorary treasurer is Mr. G. E. Hickman, of Drummond Bros.

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INSTITUTION OF ENGINEERS IN CHARGE

Though the Institution of Engineers in Charge was founded on July 5, 1895, it was not until ten years later that the custom was instituted of having an annual dinner, so that the dinner which was held on Friday, March 25, under the chairmanship of the President, Mr. R. L. Quertier, B.Sc., A.M.I.C.E., M.I.Mech.E., was the 50th; a circumstance which was reflected in the reminiscent character of the speeches. The guests were received by the President and the Vice-Chairman, Mr. F. E. Shaw. The Rt. Hon. Lord Sempill, A.F.C., F.R.Ae.S., who proposed the toast of "The Institution," observed that the function was probably the last that would be held in the Holborn Restaurant, soon to close, and recalled memories of some of the eminent "founding fathers" of the Institution who had foregathered there—Sir Richard Glazebrook, Sir Joseph Petavel, Dr. H. S. Hele-Shaw, Sir James Swinburne, and others.

Sir William J. Larke, K.B.E., proposed the toast of "Our Guests and Friends," expressing particularly the general regret of those present at the enforced absence, by reason of his advanced years, of Captain A. E. Penn, the honorary secretary of the Institution. Dr. W. A. Macfarlane, Director of the National Fuel Efficiency Service, acknowledged the toast on behalf of the numerous guests.

PERSONAL

MR. PETER MASEFIELD, M.Inst.T., chief executive officer of British European Airways, is to succeed SIR GILMOUR JENKINS, K.C.B., K.B.E., M.C., M.Inst.T., as President of the Institute of Transport, 80 Portland-place, London, W.1, on October 1.

LORD KERSHAW, O.B.E., J.P., has been appointed chairman of the two major companies in the Group being developed by MR. H. W. BOWEN, O.B.E., M.I.Mech.E., who, last year, took over the ownership of High-Pressure Components Ltd. Since then Mr. Bowen, who was formerly managing director of E.M.I. Factories Ltd., has taken over Sun Engineering (Richmond) Ltd., and its subsidiary company, Davies Coleman Ltd. Mr. Bowen will continue as deputy chairman of the Group and managing director of High-Pressure Components Ltd., while SIR WOLSTAN DIXIE is continuing as general manager of High-Pressure Components Ltd.

MR. W. U. SNELL, M.I.Mech.E., M.I.Prod.E., A.F.R.Ae.S., has been appointed executive assistant to AIR COMMODORE F. R. BANKS, C.B., O.B.E., F.R.Ae.S., M.I.Mech.E., director of the Bristol Aeroplane Co. Ltd., Filton House, Bristol.

MR. J. E. CALVERLEY, M.I.E.E., M.I.Loco.E., who since January, 1952, has been engaged on special consultancy duties for the English Electric Co. Ltd., Marconi House, Strand, London, W.C.2, has retired.

MR. W. B. G. COLLIS, M.B.E., T.D., B.Sc., A.C.G.I., A.M.I.E.E., A.I.Loco.E., has been appointed manager traction department, British Thomson-Houston Co., Ltd., Rugby, in succession to the late MR. E. T. HIPPISLEY, as from to-day, April 1.

MR. A. T. S. ZEALLEY, who recently retired from the board of I.C.I. Ltd., has been appointed by the Minister of Labour and National Service to be a director of Remploy Ltd., the company established by the Government to provide sheltered employment for severely-disabled persons.

MR. W. F. PEARCE, M.I.Mech.E., M.I.H.& V.E., chief engineer and general manager, the National Boiler and General Insurance Co. Ltd., National Buildings, St. Mary's Parsonage, Manchester, 3, is to retire on April 30. His successor will be MR. W. D. C. GOLDIE, A.M.I.Mech.E., at present assistant chief engineer.

MR. F. S. P. TURNER, A.M.I.C.E., senior executive assistant in the office of the new-works engineer, London Transport Executive, has been appointed a principal executive assistant and will be responsible to the new-works engineer for the schemes, Parliamentary plans and design section of this office.

MR. G. M. WELLS, London manager since 1939, and MR. I. G. HOPKINSON, works manager since 1947, have been appointed directors of Hopkinsons Ltd., Huddersfield.

MR. S. B. HARTSHORNE, A.M.I.Mech.E., has been appointed chief development engineer of Henry Meadows Ltd., Fallings Park, Wolverhampton.

MR. W. V. BINSTEAD has joined the development department of the British Welding Research Association, 29 Park-crescent, London, W.1, as a development engineer. MR. A. G. THOMPSON, a member of the Research Association staff, will be attending the intra-European Mission for the comparative study of welding techniques as a specialist in welding productivity nominated by the European Productivity Agency.

MR. J. D. MOSLEY, B.Sc.(Eng.), A.M.I.E.E., of the Metropolitan-Vickers Electrical Co. Ltd., Trafford-park, Manchester, 17, is now the company's district erection engineer for London.

MR. W. CHARLES WAGHORN has been elected President of the British Plastics Federation in succession to MR. C. F. MERRIAM. MR. A. E. SKAN has been re-elected chairman, MR. C. C. LAST, vice-chairman, and MR. H. W. GRAESSER-THOMAS, hon. treasurer.

MR. GORDON A. HICK is joining the staff of Whitlock Bros. Ltd., agricultural and industrial engineers, Great Yeldham, Essex, as sales director, with effect from April 4.

MR. A. G. F. FARQUHAR, O.B.E., Comp.I.E.E., assistant secretary in the Electricity Division of the Ministry of Fuel and Power, has been appointed deputy secretary of the British Electricity Authority.

MR. CLIFFORD HOLLOWELL is taking up the position of publicity manager in the commercial division of D. Napier & Son Ltd., London, W.3., in succession to the late Mr. A. V. BELLAMY.

MR. A. I. O. DAVIES has been appointed technical sales manager to Smiths Aircraft Instruments Ltd. He will take over all the duties previously performed by the late MR. G. T. PERKINS.

DR. GERHARD SCHAUDT, of Germany, has been elected President of the European Committee for Co-operation of the Machine Tool Industries. He will hold office for the next two years.

MR. T. P. COLLIER, of Chicago, has been appointed sole and exclusive representative, in the United States, of the Plessey Co., Ltd., Ilford, Essex.

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COMMERCIAL

DOWTY NUCLEONICS LTD. has been registered as the new title and trade name of DAVIS, WYNN AND ANDREWS, acquired as announced on page 329 *ante*, by DOWTY GROUP LTD., Cheltenham. The new board of directors includes MR. E. J. NICHOLL and MR. L. T. P. BANBURY, as well as MR. G. H. DOWTY and MR. T. D. H. ANDREWS.

THE CAMBRIDGE INSTRUMENT CO., LTD., have established a MECHANICAL THERMOMETER DIVISION at their additional factory at Friern-park, North Finchley, London, N.12 (Telephone: HILLside 5016), to deal with their increasing business in mercury-in-steel indicating and recording thermometers, vapour-hour pressure dial thermometers, automatic temperature regulators and similar equipment. Correspondence regarding all other types of instruments should be addressed, as hitherto, to the firm's head office, at 13 Grosvenor-place, London, S.W.1.

CARTER GEARS LTD., Thornbury-road, Bradford, 3, Yorkshire, have appointed T. K. Steanes & Son Pty. Ltd. 418 Military-road, Mosman, N.S.W., Australia (Telegrams: "Steanes Sydney"), to look after their interests in Australia.

BURTON, GRIFFITHS & CO. LTD., Mackadown-lane, Kitts Green, Birmingham, 33, have entered into an agreement whereby they have become the sole agents in Great Britain for the machine tools produced by SCHIESS A.G., Düsseldorf, Germany, with the exception of gear-hobbing equipment. ALFRED HERBERT LTD., Coventry, are to be the sole selling agents for Schiess gear-hobbing machines.

THE BUTTERLEY CO. LTD. have removed their London office from 20 Ashley-place to 9 Upper Belgrave-street, S.W.1. (Telephone: SLOane 8172-3 and 9106-7.)

WICKMAN LTD., Coventry, inform us that the London address of ARC MANUFACTURING CO., LTD., is now 15 Hercies-road, North Hillingdon, Middlesex. (Telephone: Uxbridge 5136.)

BABCOCK & WILCOX, LTD., Babcock House, Farringdon-street, London, E.C.4, announce the fusion of the trading activities of two of their subsidiary companies, SPENCER-BONECOURT, LTD., and the CLARKSON THIMBLE TUBE BOILER CO. LTD. The name of the former company has been changed to SPENCER-BONECOURT-CLARKSON LTD., and this has assumed responsibility for all new business in Spencer-Bonecourt waste-heat boilers, the Clarkson marine and industrial waste-heat, oil and gas-fired boilers and the new Autoheat oil-fired domestic boiler. The chairman of the company is CAPTAIN (E) W. GREGSON, R.N.R., M.Sc.(Eng.), M.I.C.E., M.I.Mech.E., formerly chairman of Spencer-Bonecourt Ltd. MR. S. W. SPURR, M.Inst.F., managing director of the Clarkson Co., becomes managing director, while MR. A. E. WATKINS, M.I.S.I., M.Inst.F., becomes deputy managing director of Spencer-Bonecourt-Clarkson Ltd. The secretary is MR. J. H. WORLLEDGE, and the offices remain at 14 Fetter-lane, London, E.C.4.

BRITISH PETROLEUM CHEMICALS LTD., and ORONITE CHEMICAL CO., San Francisco, U.S.A., have jointly formed a new company named GRANGE CHEMICALS LTD. This will take over, on completion, the plant which British Petroleum Chemicals is building at Grangemouth for the production of Alkylate, a product used in the manufacture of synthetic detergents.

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CONTRACTS

Cargo Motorships. An order for four cargo motorships has been placed by the Silver Line, Ltd., Palmerston House, 51, Bishopsgate, London, E.C.2, with shipyards in Sunderland. The aggregate value of the contracts is £2 million, and the ships are due to be delivered in 1957. Two of the ships, each of 11,700 tons will be constructed by SIR JAMES LAING & SONS, LTD., the third, of 11,950 tons, will be built by BARTRAM & SONS, LTD., South Dock, and the fourth, of 10,000 tons, by JOHN CROWN AND SONS, LTD. The propelling machinery of the four vessels will be built by WILLIAM DOXFORD & SONS, LTD., also of Sunderland.

Jet-Engine Test Plant. A contract from the Royal Swedish Air Force to supply one of their latest

jet engine test plants has been received by HEENAN AND FROUDE, LTD., Worcester. This plant will consist of an engine thrust cradle (rating 15,000 lb. maximum thrust), jet pipe support, engine auxiliary loading gear, starting equipment and other apparatus. Heenan and Froude will also supply remote thrust measuring gear, engine controls and the complete instrumentation of the main-control panel and feed cubicle. The design is based on the "F"-type cradle as exhibited at Farnborough last year.

Air Liners. El Al Israel Airlines have decided to acquire three Bristol Britannia Mark 300 LR air liners from the BRISTOL AEROPLANE CO. LTD., Filton House, Bristol, and have asked for an option on two further aircraft.

Underground-Railway Equipment. Contracts to the value of some £200,000 have been placed with the GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2, by the Metropolitano de Lisboa, S.A.R.L. Portugal, for power supply, ventilating and pumping equipment for the first underground railway in Portugal. The Metropolitano will be a 4-ft. 8½-in. gauge railway operating at 750 volts D.C., and will be constructed mainly on the "cut-and-cover" system, although short sections will require tunnelling. Stage one of the project, for which the present contracts have been placed, involves the line from Restauradores to Entre Campos and a branch from Rotunda to Sete Rios, with a spur to workshops, a total of some 4·3 route miles. The planned total mileage of the system is 11·97 route miles, and extensions which would bring the total to 25·7 route miles are in view.

At the main substation, where power is taken at present from the supply undertaking at 10 kV, the G.E.C. is supplying a 7-panel 10-kV oil circuit-breaker switchboard, a 1,000-kVA, 10-kV/3-kV transformer, and an 11-panel 3-kV switchboard for controlling supplies to auxiliary services. Stand-by auxiliary power will be provided by a 1,000-h.p. Diesel-alternator set, comprising a 1,000-h.p. RUSTON-PAXMAN 12 YLX engine coupled to a G.E.C. alternator. The complete A.C. and D.C. switchgear installation at the traction substation is being supplied by the G.E.C., as well as rectifier equipments and transformers. The firm is also responsible for the supply and erection of the ventilation system for the tunnels and stations.

Hydro-Electric Plant. An order from the North of Scotland Hydro-Electric Board, placed recently with GILBERT GILKES AND GORDON LTD., is for two turbines for the Shin project. They comprise a 456-b.h.p. Francis turbine and a 177-b.h.p. Turgo impulse wheel, for installation in the Cassley aqueduct power station. They will each be coupled to an induction generator, manufactured by BRUCE PEEBLES & CO., LTD., Edinburgh. An order has also been received from the Union Electric Light and Power Co. of Newfoundland, for a 2,000-b.h.p. Francis turbine which is to supply power to the isolated Bona Vista Peninsula and augment the overloaded existing plant. This turbine is to be governed by the patent "Giljet" governing system.

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OBITUARY

We regret to record the deaths of:

MR. JOHN HENRY WALES LAVERICK, J.P., D.Eng., M.I.C.E., M.I.Min.E., at his home in Collegiate Crescent, Sheffield, on March 23, in his 90th year. Mr. Laverick was well known throughout the coal industry of this country and was for many years managing director of the Tinsley Park Colliery Co., Ltd., and a director of many other colliery undertakings, at Barnsley, Pontefract, Shirebrook, Shireoaks, Castleford and elsewhere. He did much pioneer work in the introduction of coke-oven gas for use in connection with the public supply in Sheffield and was a director of the South Yorkshire Gas Grid Co., Ltd. For his services to the University of Sheffield, the honorary degree of D.Eng., was conferred upon him in June, 1932. He was for many years a member of the Iron and Steel Institute and was a past-president of the Midland Institute of Mining Engineers.

MR. HERBERT F. CRAGGS, at his home at Brough, East Yorkshire, on March 19, at the age of 86. Mr. Craggs was chairman of the Goole Shipbuilding and Repairing Co., Ltd., Goole, and of Clelands (Successors), Ltd., Willington Quay-on-Tyne.

MR. ALBERT VICTOR ROBINSON, at Sandal, Wakefield, on March 17, at the age of 57. Mr. Robinson was works manager of E. Green and Son Ltd., Economiser Works, Wakefield.

WROUGHT NON-FERROUS METALS AND ALLOYS*

A SURVEY OF THE PAST 36 YEARS

By Maurice Cook, D.SC., PH.D.†

Up till the time of the first world war, melting and casting practices were based almost entirely on the skill and experience of operatives, but with the advent of new alloys, the demand for increased output and castings of much greater size, the craftsman's skill alone was unequal to the task of improving or even maintaining ingot quality, and techniques based on scientific practice began to be introduced and have since been continued by the implementation of the results of research.

As long as forty years ago the work of Sieverts and his collaborators indicated that molten metals dissolve large volumes of gases, the release of which, during solidification, might account for ingot unsoundness, and over the last thirty years metal-gas reactions have been the subject of much successful research. Conspicuous in studies of gas equilibrium with copper has been the work of Allen and Hewitt on the combined effect of oxygen and hydrogen, and of Floe and Chipman on the role of sulphur.

That the gas hydrogen was a cause of unsoundness in aluminium-alloy castings was recognised in 1929 by Claus, who showed that it originated from the decomposition of water by molten aluminium. This was confirmed in 1931 by Hanson and Slater, who, among others, demonstrated the efficacy of treatments with chlorine or nitrogen for the removal of hydrogen, procedures which have since become normal industrial practice.

Realisation of the ill-effects of gases led to the accelerated adoption of electric melting, utilising arc, resistance, high- and low-frequency induction furnaces, and some of these have now almost entirely replaced other forms of melting in many sections of the industry.

The introduction of the copper-faced water-cooled mould, of the kind devised by Junker in about 1926, was a most noteworthy advance in casting practice, and water-cooled moulds of this type are quite generally employed in brass and copper mills. Their use in place of cast-iron strip and billet moulds has perhaps been responsible for a greater improvement in ingot surface, internal soundness, and crystal structure than any other modification in casting technique and it has, moreover, greatly facilitated the production of large ingots of good and uniform quality, required for modern large-scale plants.

CONTINUOUS CASTING

The use of continuous casting is another outstanding innovation and the method originated by Junghans, some 25 years ago, has been successfully applied in the casting of brass alloys, and more recently for copper. The increase in the demand for aluminium alloys in recent years focussed attention on the need for better casting techniques. The production of sound ingots depends, among other things, on the non-turbulent filling of the mould, and for many alloys rapid chilling is needed to obtain the necessary fine dispersal of phases. Following the lead of Junghans's work on the continuous casting of brass, in 1936 German investigations showed that by using a short mould and effecting most of the cooling by the direct application of water to the solidified ingot skin, a greater degree of chilling could be obtained than by conventional casting methods. Processes of this type, known as semi-continuous, proved to be so successful in yielding good-quality products that they were rapidly developed, and in less than ten years became standard practice in the wrought-aluminium industry throughout the world, and now they are beginning to be used for the casting of copper and copper alloys.

Before I leave melting and casting I must mention the new technique that has been devised for metals of high melting point. Fifteen years ago it was used on a laboratory scale for melting very small amounts of metal, that is, buttons weighing only a few ounces, but now furnaces of this kind are in operation for producing ingots of up to 2 tons. Not only is it novel and interesting technically, but it is the only method at present known for melting in quantity such materials as molybdenum, titanium, zirconium and their alloys. The metal is melted by means of an arc in vacuo, or in an inert atmosphere such as argon in a water-cooled copper crucible. The metal is either fed into the furnace as small pieces, and an arc struck between it and an electrode of tungsten or carbon, or the metal to be melted may itself constitute the electrode. In either case metal is melted by the heat of the arc and an ingot progressively built up, the molten pool being maintained at a constant depth either by raising the electrode or lowering the base of the copper crucible.

STRIP ROLLING MILLS

From slow, simple, ponderously-driven machines, rolling mills have been transformed over a span of relatively few years into highly-mechanised precision units capable of rolling heavy weights of metal accurately at high speeds. In general it can be said that the rolling of long lengths of coil in wide widths reflects the chief difference in strip and sheet rolling practice to-day compared with that of thirty years ago when narrow coils of small weight were produced by slow-speed rolling on two-high mills.

Broadly speaking the commencement of the modernising movement in non-ferrous strip rolling dates from about the second decade of this century, but it was not until the 1920's that it became appreciable. Since then two-high mills have been altered out of all recognition, and various types of multi-high mills have been devised and put into service. With these mills have come mechanisms for feeding, coiling and tensioning, devices for the automatic adjustment of rolls and gauge, recording instruments, and other items of ancillary equipment to facilitate their efficient operation. Forty years ago the speed of cold-rolling strip mills rarely exceeded about 70 ft. per minute, but on modern mills speeds of about 1,000 ft. per minute are quite usual and speeds of 2,000-4,000 ft. per minute not uncommon.

Other types of multi-high mills have more recently made their appearance such as the Steckel mill in which all the energy of rolling is transmitted by the coiler and decoiler, and the Sendzimir mill with working rolls as small as a quarter of an inch in diameter, which not only reduces power requirements but facilitates rolling of strip in wide widths to thin gauges, particularly in harder alloys. For hot rolling, a recent and novel plant is the Planetary mill, which would appear to have considerable possibilities. On this mill reduction is effected by a number of small-diameter rolls symmetrically disposed around the circumference of the rolls of a two-high mill and it is possible to obtain, in one pass, a greater reduction than can be achieved in ten or more passes on conventional hot rolling mills.

TUBE-MAKING PROCESSES

While some of the improvements effected in tube manufacture during the last 25 years relate

* Presidential Address delivered before the Institute of Metals at the Annual General Meeting on Wednesday, March 30, 1955. Abridged.

† Joint managing director, Imperial Chemical Industries Ltd., Metals Division, Birmingham, 6.

to the production of tube shells, the most radical changes have been in drawing operations. Drawing on mandrels in short lengths, that is, about 20 to 30 ft., at speeds rarely exceeding 100 ft. per minute, on single-hole benches, was the method generally employed for many years, and the first major change began to take place in the early 1930's with the introduction of fixed plug drawing which made possible the processing of longer lengths at higher speeds and, moreover, the drawing of several tubes simultaneously. The years immediately following saw the further development of this method and also of the floating plug technique, as well as multiple drawing, so that towards the end of the 1930's fully automatic triple draw benches began to appear in the tube mills of this country, followed more recently by highly-mechanised triple-draw benches with capacities up to 300,000 lb. pull, and able to draw tubes up to 150 ft. long, at speeds of about 350 ft. per minute.

The work on plug design which made it possible to dispense with the plug rod and allow the plug to float, opened the way for block drawing, in which tubing, reduced by conventional methods to 2 in. diameter or less, is further drawn on bull blocks, coiled after each draw and left either in long coils or alternatively straightened and cut to required lengths. This method has made possible the production of tubing in much greater lengths than could formerly be manufactured by other drawing techniques and at drawing speeds of up to 1,800 ft. per minute.

Markedly accelerated by the expanding use of light alloys, there has been in recent years a considerable growth in the output of extruded materials, and much has been achieved in improving the design and operation of extrusion presses and also in greatly increasing their capacity and range of products. Numerous interesting modifications have been made in extrusion practice and among these some of the more important include the use of more durable materials for dies, mandrels and other components, of glass as a lubricant, and the introduction of techniques for the production of hollow, tapered and stepped extrusions.

PROGRESS IN CONDENSER TUBE MANUFACTURE

Before the period with which we are concerned, the copper alloys in general use were a range of brasses, gunmetals, tin bronzes, cupro-nickels and nickel silvers. In all of these groups new and improved alloys have been produced in the past two or three decades, but many other new copper-base alloys have also been developed to meet the growing and varied needs of industry. To comment, however briefly, on all of these would occupy much more time than is now available to me and I propose therefore to confine myself to two groups of alloys, one which represents an important usage and illustrates much progress, that is, for condenser tubes, and another, age-hardening alloys, which possibly have an interesting future.

Condenser tubes of 80/20 cupro-nickel were first made in 1921 in this country. In 1925 this alloy was superseded by 70/30 cupro-nickel which was shown to be markedly superior, and tubes of this latter alloy, after approval by the Admiralty, were adopted in 1927 as standard for the Royal Navy and formed the subject of a specification in 1930. Investigations which stemmed from variability of performance of tubes in service showed that relatively small amounts of iron and manganese, especially the former, greatly improved the resistance of the alloy to corrosion, and particularly to impingement attack. In consequence the specification was modified in 1934 to include iron plus manganese and later changes cover up to 1·0 per cent. iron and 1·3 per cent. manganese. This is the type of cupro-nickel that has been developed after years of experiment and experience, and is now generally fitted in the condensers of naval vessels and large ocean-going liners, and used in many land power stations where the condensing systems have to contend with severe corrosive conditions.

At one time it was thought that aluminium in brass impaired the corrosion resistance of the alloy, but work done in the early 1920's at Woolwich for the British Non-Ferrous Metals Research Association and later in the Association's laboratories showed, on the contrary, that it was indeed most beneficial, and thereafter a brass of the alpha type containing about 2 per cent. aluminium was developed as a condenser-tube material. It would seem to have been first so employed in about 1929 and since then its use in this and other applications has continued to increase. The presence of this amount of aluminium also greatly improves the resistance of brass to oxidation at elevated temperatures, for at 775 deg. C., for example, the rate of oxidation is only about one-fortieth that of a straight brass.

Corrosion which gives rise to dezincification in brass alloys was at one time a serious trouble, and the investigators to the Corrosion Committee of the Institute established in 1910 devoted much effort to studying the causes and prevention of dezincification. In about 1923 a considerable variability of performance in service of brass condenser tubes was traced to the presence or absence of arsenic. This observation was confirmed and for the past thirty years it has been a common, if not general, practice in this country to add arsenic in amounts of about 0·02 to 0·05 per cent. to alpha-brass alloys for service where resistance to corrosion is an important consideration.

As a footnote to this work on condenser tube materials I might add that the British Non-Ferrous Metals Research Association extended its studies on the effect of iron on alloys of lower nickel content, and alloys of this range of composition, that is, up to about 10 per cent. nickel with iron contents up to 2 per cent., with good corrosion resistance and capable of easy manipulation, have been developed for other sea-water carrying pipes in ships and power stations.

The use of copper alloys extends over thousands of years and their production has featured in the industrial development of this country for centuries. Despite this long history, nothing was heard of heat-treatable copper alloys until about the middle of the 1920's. About that time the investigations of Corson, Masing, Fraenkel and others revealed that several copper alloys could be hardened by heat-treatment alone. The outstanding example was the copper-beryllium alloys which, with other alloying additions, were studied in considerable detail and have since been developed more than any other heat-treatable copper alloys. Since then the number of age-hardenable copper-base alloys which have been found runs into hundreds. Many of these have not been studied in any detail but a few, notably those containing nickel with additions of silicon, aluminium, manganese, tin or phosphorus, and those containing chromium, have been used industrially to some extent, and papers dealing with some of these have appeared in the *Journal* of this Institute. As Merica said more than twenty years ago in speaking of alloys which are hardenable by heat-treatment alone, such alloys may be the rule rather than the exception among alloying systems.

Although there are many uses for some of these alloys the total amount produced is triflingly small in relation to other copper alloys, and thus their relative importance is very different from that of the heat-treatable alloys in the aluminium industry. There, the discovery of age-hardenable alloys opened up a wide vista of possibilities for aluminium, when that metal was still in its infancy, and the development of alloys of this type contributed greatly to the growth of the light-metals industry and are to-day an important part of its production.

ALUMINIUM ALLOYS

From a level of about 5,000 to 10,000 tons at the beginning of the century the world production of aluminium has risen to about 3 million tons in 1954, and in this country the output of semi-fabricated products in this metal and its alloys has increased three- or four-fold in the last fifteen years. This spectacular growth in the production of these materials reflects the greatest change that has taken place in the pattern of production of wrought non-ferrous metals in modern times. Associated with this vast expansion there have been improvements in production technology of a most impressive kind, and also in further fabrication and finishing processes.

TITANIUM IN INDUSTRY

The last few years have seen the advent of titanium as a new industrial metal, and the technical achievements that have made this possible are among the most interesting in the period with which I am concerned. The whole production of titanium and its alloys is dominated by the need for, and the difficulty of, avoiding contamination by impurities, and the history of this metal and its technology provides surely one of the most vivid illustrations of just how important impurities can be.

Titanium was discovered in 1790, but for 135 years knowledge of its properties was hidden from us by the masking effect, as we now know, of impurities such as oxygen and nitrogen in particular. Prior to 1925, it was known only as a brittle unpromising metal, but in that year the Dutch chemists van Arkel and de Boer produced metal of about 99·9 per cent. purity which was quite different from that hitherto made, inasmuch as it was very ductile and readily workable in the hot and cold states. Elegant though it was, the method used by van Arkel and de Boer of thermally dissociating the tetra-iodide of titanium formed at much lower temperatures could not be, and has not yet been, translated into an industrially workable process. However, as a result of their work it became possible to determine the real properties of titanium, and this information pointed the way to an important and growing future for the new metal. The worthwhile objective was there for the development of a less costly extraction process which would yield acceptably pure metal. To Kroll, working at that time in Luxembourg, goes the credit for devising and developing the first process to be used on an industrial scale for the extraction of titanium. In 1940 he was granted a patent for the production of titanium by reduction of the tetra-chloride with metallic magnesium, with subsequent removal of the residual magnesium and magnesium chloride by leaching. This pioneer work was continued in the United States under the auspices of the Bureau of Mines, and details of the various techniques developed were made known in 1946. Industrial production started modestly in the United States in 1948 with an output of about 15 tons. In 1954 this probably reached, in total for the world, although most of it was American, about 4,000 tons, and the capacity of existing and projected plant in the United States is reputed to be about 35,000 tons. It has been suggested that the demand could soon reach six figures and it would seem quite probable that an output of this magnitude might well be achieved in the next few years.

Tin-plate accounts for about half the total consumption of tin, and its annual output, which runs into millions of tons, is produced on some of the most imposing plant employed in the metallurgical industry. The changes that have revolutionised production methods have been the introduction of large powerful mills for rolling wide strip in coils weighing several tons, and of electrolytic tinning with the consequent creation of an effectively integrated large-tonnage continuous process yielding a product of consistent quality. These plants indeed impress by their immensity, capacity and efficiency, and the accomplishment of implementing, within one decade, research work on electro-tinning into a continuous industrial process on a vast scale, must surely rank as one of the most striking metallurgical successes of our time.

BOOK REVIEWS

Acoustics. By LEO L. BERANEK. *McGraw-Hill Book Company, Incorporated,* 330 *West* 42*nd-street, New York* 36, *N.Y., U.S.A.* (9 dols.); and *McGraw-Hill Publishing Company, Limited,* 95 *Farringdon-street, London, E.C.*4. (64*s.*)

Since the formation of the Acoustical Society of America in 1929, the number of text-books on acoustics, and particularly on applied acoustics, has greatly increased. The author of this volume, which forms part of the McGraw-Hill Electrical and Electronic Engineering Series, is the present holder of the office of President of that Society and has had considerable experience, both academically as a member of the staff of the Department of Communication Engineering at the Massachusetts Institute of Technology and practically as a director of a well-known firm of consultants in acoustics.

Thus it is the engineering aspects of acoustics that are stressed in this text. Such classical topics as the vibrations of strings, membranes, bars and plates are barely mentioned, except for certain results concerning the vibrations of crystal slices and diaphragms quoted in the sections dealing with microphones and loudspeakers. Within these limits, however, the treatment is remarkably thorough and the inclusion, among the preliminary suggestions, of a minimum of ten experiments which ought to be performed in conjunction with the study of the text is to be warmly commended.

M.K.S. units are employed throughout and definitions of the principal acoustical magnitudes are given at the outset in terms of these units. Their advantages soon become evident, and a table of conversion factors is provided to enable such units to be converted into their more familiar C.G.S. or British equivalents. The basic wave equations for one and three dimensions are derived in parallel columns, using vector notation for the latter; the relevant solutions for plane and spherical progressive waves are deduced and discussed, and expressions for energy density and intensity obtained. This is followed by a systematic exposition of methods for handling combined electrical, mechanical and acoustical systems based on analogies of the impedance and mobility types. Here, as elsewhere, the clear diagrams and worked examples will give the reader confidence in tackling practical problems. Responsiveness, being the reciprocal of a resistance, will not be measured in ohms as stated on page 54.

Consideration is then given to the directivity patterns and radiation impedances of various simple sources, such as the pulsating sphere, acoustic doublet, circular piston in an infinite baffle or at one end of a cylindrical tube, together with more complicated curved line and multicellular horn sources. Microphones of the pressure, pressure-gradient and combined pressure and pressure-gradient types are next described and their equivalent circuits over various frequency ranges analysed. The three chapters devoted to loudspeakers deal comprehensively with moving-coil units of the direct radiator type as well as with those in which horns of the exponential, parabolic, conical and hyperbolic form are interposed between the diaphragm and the air. Detailed consideration is given to the physical properties of loudspeaker housings of the closed-box baffle and bass-reflex types, and the systematic summaries of design factors accompanied by a large selection of response curves are particularly noteworthy. The study of sound in enclosures begins by considering the normal vibration modes of the air within a small rectangular room and then goes on to treat sound fields in large irregularly shaped enclosures and sound transmission through walls. The increasing importance of noise, and measures for its reduction, are explained in Chapter 11. The outline of the measurement of sound pressure levels and the reciprocity calibration of transducers is based on the author's previous book *Acoustic Measurements*, while the final chapter is concerned with hearing, speech and intelligibility and psychoacoustic criteria.

Professor Beranek's book is fully abreast of modern developments, to which he himself has made significant contributions, and includes a good deal of material not previously given text-book presentation in a form suitable for direct application by engineers engaged upon acoustic problems ranging from high-fidelity sound reproduction to noise control.

Welding for Engineers. By HARRY UDIN, EDWARD R. FUNK and JOHN WULFF. *John Wiley and Sons, Incorporated,* 440 *Fourth-avenue, New York* 16, *N.Y., U.S.A.* (7·50 dols); and *Chapman and Hall, Limited,* 37 *Essex-street, London, W.C.*2. (60*s.*)

The authors of this book have given a clear indication of their approach to the subject in the title, and the object and scope are clearly set out in the preface. The book is based on notes used as text material in a course at the Massachusetts Institute of Technology, which is attended by students with a variety of backgrounds (structural and mechanical as well as metallurgical) and at diverse levels—junior, senior and graduate. It should not be assumed, however, that the book is intended and suitable only for students and young graduates. Many engineers at a more advanced stage of their careers find it necessary, due to the rapid development of welding techniques and their application, to acquire a knowledge of the fundamental principles of the art and science of welding. To such, especially those whose knowledge of basic science is somewhat rusty, the book will be of value.

The opening chapter commences with brief historical notes on welding processes and continues with the customary classification, the main divisions being welding with pressure and welding without pressure. The metallurgists' classification into autogenous, homogeneous, and heterogeneous welding is explained—a point which many text-books omit. The chapter concludes with a review of the problems of the welding engineer and the scope of welding engineering, with useful comments and suggestions on the training of welding engineers.

Chapters 2 and 3 deal with cold welding, and hot pressure welding (solid-phase welding), respectively, and the fundamentals of these processes are explained in a manner that will be found in few, if any, general text-books on welding. It is disappointing to find no reference to the extensive fundamental work in this country by Tylecote; but there is a general tendency on the part of American technical authors to overlook work done in other countries. The fundamentals of the various resistance-welding processes are covered in Chapter 4, and the next chapter discusses metallurgical reactions in resistance welding. For a modern text-book there are some notable omissions (one would have liked to see more on the resistance welding of stainless steels, aluminium and the light alloys, and of modern heat and creep-resisting materials), but in a general text-book on such a wide subject as welding, space is often a ruling factor.

A feature not usually found in general text-books on welding is the chapter on heat and temperature during fusion welding. It contains the equations for heat flow, the temperature distribution in thin, thick and semi-infinite plates; the effect of welding speeds, heat input and preheat are explained, and a comparison is made of rates of heating and cooling in aluminium and steel. The fundamentals of the welding arc are dealt with in the chapter on permanent-electrode arc processes, which concludes with some of the main principles of inert-gas-shielded tungsten arc welding and brief notes on the carbon-arc and atomic-hydrogen processes.

In view of the fact that the inert-gas shielded consumable electrode process originated in the United States, and that so much important development of the process has taken place (and is still taking place), it is surprising to find this process very inadequately treated in about two pages. The basic principles of coated electrodes are explained; and the student and engineer will find very useful the typical analyses of electrode coatings and the explanation of the United States classification coding of electrodes which differs so much from the British and European systems. Two chapters are devoted to the metallurgy of fusion welding and this important aspect of the subject is presented in a manner which should be readily understood.

Braze (or bronze) welding, the metallurgy and mechanics of brazing and the thermodynamics and hydromechanics of the process are dealt with in the following chapters, and the book concludes with useful chapters on mechanical effects encountered in welding (distortion and residual stresses), and principles of weld inspection and testing.

This is not just another book on welding. It is written with a specific object by men having a full appreciation of the basic technical requirements of the engineer, and their presentation and treatment of the subject is novel in many respects. It is generally well up-to-date and contains much material not usually found in general text-books on welding. The few omissions or points not dealt with as fully as could have been wished will not prevent the student and engineer from acquiring a better understanding of welding processes, the why and wherefore of welding procedures and techniques, and arriving at solutions to their welding problems by a careful study of this book.

A Review of Productivity in the Bronze and Brass Casting Industry. *The British Productivity Council,* 21 *Tothill-street, London, S.W.*1. (2*s.* 3*d.*)

Brassfounding is widely distributed throughout the United Kingdom, with a major concentration in the Midlands and smaller groupings in Yorkshire and the London area. If the term be used in its widest sense, to include all the copper-base alloys, brassfounding is the oldest of all the branches of the foundry industry. Perhaps owing to its long tradition, and also because many of its units are small, the industry has shown some reluctance to adopt new ideas. Where the capital resources of individual firms are small, co-operation is essential, but it has not been conspicuous in the past.

In 1950 a Brassfoundry Productivity Team visited the United States, and their report contained many suggestions of value to the British industry. The present review shows what has been done to implement these suggestions. The adoption of new techniques has not been as widespread as it might have been, but some satisfactory developments are noted.

In particular, attention is drawn to some of the results achieved by very small firms. It is as well that this point should be stressed, for there is still a widespread impression that the adoption of new techniques and the installation of new equipment are matters for large concerns with adequate capital resources, and that small undertakings can do little to improve their methods. That this is not always true may be illustrated by the case history of a firm of brassfounders with a labour force of only ten. This firm spent a few thousand pounds on new equipment and reorganisation. As a result, output has increased, the employees are receiving higher wages than before, and, within two years, the capital expenditure has been recovered.

Case histories of other firms are included in the review. They range from small to large undertakings, all of which have improved their methods, techniques or plant (in some cases all three), with considerable advantage. It is shown that, technologically, the industry has made great strides since 1950, particularly in the development of shell-moulding, but that much remains to be done by individual concerns. Job simplification, mechanisation, and the improvement of working conditions are especially worthy of close study.

BOOKS RECEIVED

Some of the books noticed here are selected for extended review in later issues of ENGINEERING.

Optical Glassworking. By F. TWYMAN, F.R.S. *Hilger and Watts, Limited (Hilger Division), 98 St. Pancras-way, Camden-road, London, N.W.1.* (24*s.*)

Mr. Twyman's first book on *Prism and Lens Making*, issued during the war, described the methods in use in the optical workshops of Adam Hilger, Limited, now Hilger and Watts, Limited (Hilger Division), its object being to assist those entering the industry at that time. A second enlarged edition was issued in 1952, covering subsequent developments and dealing fully with practices only briefly referred to in the first edition. His new book, *Optical Glassworking*, is an abridged version of this second edition, the author having compiled it for use by those actually engaged in optical work. It covers tools and materials, the quantity production of lenses and prisms, the production of spectacle lenses, microscope lenses and non-spherical surfaces. Chapters are devoted to the testing of optical work and there is a chapter on the treatment of surfaces by chemical silvering and evaporation processes. The last chapter explains the testing of large telescope objectives and mirrors. An appendix is devoted to the making of polarising prisms and the book concludes with a glossary of French and German terms used in the optical industry.

Fifty Years of Western Express Running. By O. S. NOCK. *Edward Everard, Limited, 38 Broad-street, Bristol.* (25*s.*)

Mr. Nock's latest book is devoted to locomotive runs on the Great Western Railway (now the Western Region of British Railways) from 1904 to 1954. There are eight illustrations in colour, nearly 80 in black and white and various outline diagrams of engines. A set of seven gradient profiles is also provided to accompany the text.

Current British Directories, 1955. Compiled and edited by G. P. HENDERSON. *Jones and Evans' Bookshop, Limited, 70 Queen Victoria-street, London, E.C.4.* (25*s.*)

This is a guide to the local, trade and professional directories of the British Isles. The scope of this edition, which is produced in duplicated typescript, has been extended to include membership lists of domestic chambers of commerce, and certain directories and lists published in periodicals.

A Review of Productivity in the Bronze and Brass Casting Industry. *Btitish Productivity Council, 21 Tothill-street, London, S.W.1.* (2*s.* 3*d.*) (Reviewed on page 395.)

Centrifugal Pumps. U.S. Case Study Data on Productivity and Factory Performance. Prepared for the Foreign Operations Administration, Industrial and Technical Assistance Division, by the U.S. Department of Labor. Distributed in Great Britain by the *British Institute of Management, 8 Hill-street, London, W.1.* (5*s.*)

The object of this report is to enable production managers to compare their plant with a similar American one. The report is divided into three chapters: the general picture of activity in the industry, detailed case studies of each plant, and the question of workers' earnings and their benefit from increased productivity. In addition there are appendices containing case studies of labour adjustment to technological change, and also a copy of the questionnaire used.

I.P. Engine Test Methods for Rating Fuels. *The Institute of Petroleum, 26 Portland-place, London, W.1.* (20*s.*)

This book contains the fuel rating methods which previously formed a section in the "Standard Methods" handbook. Because of the size to which the latter has grown, it will in future be published in two parts, of which this volume is one. It contains the methods currently recognised for the knock rating of Diesel, aviation and motor fuels, using the C.F.R. engine.

The Price of Electricity: Its Relation to Investment in the Electricity Supply Industry. *The Organisation for European Economic Co-operation, 2 Rue André-Pascal, Paris 16e.* (200 francs); and *H.M. Stationery Office, Kingsway, London, W.C.2.* (4*s.*)

During 1953 a group of experts of the O.E.E.C. undertook, on the international level, a study of electricity prices and their relation to investment in the industry. The first chapter of this report records the main view on which the participants agreed unanimously. In the second, reports of several of the countries are given separately and show the financial situation of the industry as well as regulations governing the present prices.

Surface Coating Resin Index. *The British Plastics Federation, 47 Piccadilly, London, W.1*; and the *Surface Coating Synthetic Resin Manufacturers' Association, 79-80 High Holborn, London, W.C.1.* (3*s.*)

This comprehensive index gives in 14 tables the basic information on all the British-made surface coating resins at present available to the paint, printing-ink and allied trades. So far as their complex chemical nature will permit, 733 resins have been classified according to type, and within each of the 14 classifications they have been listed in alphabetical order by trade name. There is a list of all the producers contributing and indexes to producers and trade names.

A Survey of the Results of the Examination of the Brickwork of Blown-Out Blast-Furnaces. By H. M. RICHARDSON and G. R. RIGBY. Iron and Steel Institute Special Report No. 51. *The Iron and Steel Institute, 4 Grosvenor-gardens, London, S.W.1.* (25*s.*; 15*s.* to members.)

This survey contains data on 79 blown-out blast-furnaces at different plants examined over the last 20 years. The work has been undertaken on behalf of the Blast-Furnace Refractories Joint Committee of the British Iron and Steel Research Association and the British Ceramic Research Association. The findings have been assembled and tabulated and form a basis for comparing the various modes of deterioration of brickwork from the top of the blast-furnace stack to the hearth.

Tables of Functions and of Zeros of Functions. U.S. National Bureau of Standards Applied Mathematics Series 37. *The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A.* (2·25 dols.)

This volume brings together eighteen short tables of functions and of zeros of functions, some of which have previously been published in American journals. It is the first of certain projected numbers in the Applied Mathematics Series to bear the sub-title *Collected Short Tables of the National Bureau of Standards Computation Laboratory*. Future volumes will contain not only tables which have previously been printed elsewhere, but also certain tables, hitherto unpublished, which have been found useful in the operation of the Computation Laboratory.

Deterioration of Materials: Causes and Preventive Techniques. Edited by GLENN A. GREATHOUSE and CARL J. WESSEL. *Reinhold Publishing Corporation, 430 Park-avenue, New York 22, N.Y., U.S.A.* (12 dols.); and *Chapman and Hall, Limited, 37 Essex-street, London, W.C.2.* (96*s.*)

Prepared with the collaboration of 24 specialists, this book describes and analyses the causes of deterioration of metals, wood and wood products, paper, textiles and cordage, leather, plastics and rubber, and paints, varnishes, enamels and lacquers. The climatic, chemical, physical and biological agents of deterioration are discussed, and dependable techniques for preventing or retarding deterioration in the materials dealt with are presented in detail.

Contributions to the Solution of Systems of Linear Equations and the Determination of Eigenvalues. Edited by OLGA TAUSSKY. U.S. National Bureau of Standards Applied Mathematics Series 39. *The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., U.S.A.* (2 dols.)

Most of the papers covered in this book deal with various aspects of the solution of simultaneous equations. The material includes a presentation of practical methods of solution illustrated by worked examples, a theoretical study of iterative procedures, manual methods of computation, experiments using punched-card equipment, and a study involving high-speed computations. Two papers deal with the rank of a matrix and the location of its eigenvalues.

Manufacture and Application of Lubricating Greases. By C. J. BONER. *Reinhold Publishing Corporation, 430 Park-avenue, New York 22, N.Y., U.S.A.* (18.50 dols.); and *Chapman and Hall, Limited, 37 Essex-street, London, W.C.2.* (148*s.*)

The author's aim in writing this book has been to produce a comprehensive work covering the structure and theory of lubricating greases, raw materials and manufacturing processes, and details of the characteristics of a wide range of lubricating greases. In all these fields there have been great advances during the past ten years. Lubricants containing specific thickeners and additives, including new developments such as lithium soaps, complex soaps and non-soap gelling agents, receive detailed attention. Emphasis is placed on the effects of each ingredient or treatment on the characteristics of the final product, and the methods of evaluating these characteristics by chemical or physical means. Chapters are included on the application of lubricating greases and trends in their development.

Packaging Engineering. By LOUIS C. BARRIL. *Reinhold Publishing Corporation, 430 Park-avenue, New York 22, N.Y., U.S.A.* (9.50 dols.); and *Chapman and Hall, Limited, 37 Essex-street, London, W.C.2.* (76*s.*)

All aspects of packaging engineering: design, labelling, testing; different materials used—wood, metal, fibreboard, glass, plastics, paper; protection against mechanical damage, corrosion, insects, etc.; special requirements of packaging for export, armed forces, drugs, cosmetics and food industries. This book is written for industrialists and production engineers, and includes a short glossary in English-French-Spanish.

Circuits and Networks. By GLENN KOEHLER. *The Macmillan Company, 60 Fifth-avenue, New York 11, N.Y., U.S.A.* (6·50 dols.); and *The Macmillan Company, New York, 10 South Audley-street, London, W.1.* (45*s.* 6*d.*)

Present-day students of power and communications electrical engineering need to have some knowledge of circuits and networks. This book deals with properties of simple frequency-selective circuits, coupled circuits, impedance matching, filters, attenuators and equalisers. To show application to power circuits, there are sections on transmission line parameters and analysis. The book is intended as a one-year course for students who are already familiar with alternating-current theory.

Copper Smelting and Refining in the U.S.A. Technical Assistance Mission No. 85, Vol. I. *Organisation for European Economic Co-operation, 2 Rue André-Pascal, Paris, 16e.* (200 francs); and *H.M. Stationery Office, Kingsway, London, W.C.2.* (4*s.*)

The purpose of a Technical Assistance Mission of European metallurgists who visited the United States between October 14 and November 22, 1951, was to attend the World Metallurgical Congress in Detroit and to visit American non-ferrous metal smelters and refineries in order to study production methods. This first volume of their report describes American copper-smelting works and gives information concerning furnace linings, refining methods and copper smelting in electric furnaces.

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TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Electronic Instruments. A/S BRUEL AND KJAER, Naerum, Denmark; Agents, Rocke International Ltd., 59 Union-street, London, S.E.1. Electronic instruments for wide range of applications, e.g., frequency response, noise level, frequency analysis, vibration, transients, acoustic properties; instruments designed for inter-connected use to minimise total equipment needed to cover several duties. Application schedule of precision electronic instruments and short catalogue.

Rotary and Static Dryers. J. DAWSON FAWCETT (DARLINGTON) LTD., Haughton Engineering Works, Darlington. Portable and continuous rotary dryers arranged for oil, coal, coke or gas firing according to type, for drying ore, rock, chemicals, limestone, etc., and for manufacturing plaster; general dimensions of single-compartment dryers. Illustrated booklet.

Positive Rotary Blowers. STURTEVANT ENGINEERING CO. LTD., Southern House, Cannon-street, London, E.C.4. Positive-type rotary piston blowers and exhausters. Capacities up to 2,900 cub. ft. per minute at pressures up to 10 lb. per sq. in. Leaflet 3301 gives range available.

Fluorescent Tubes. THORN ELECTRICAL INDUSTRIES LTD., 105-109 Judd-street, London, W.C.1. "Atlas" fluorescent tubes, leaflet gives types available, also output, energy-distribution and life curves.

Dry Gasholders. ASHMORE, BENSON, PEASE & CO., Stockton-on-Tees. ABP-Klonne type dry gasholders up to 21 million cub. ft. capacity. Illustrated brochure giving details of construction.

Oil-Break Switchgear. A. REYROLLE & CO. LTD., Hebburn, Co. Durham. 33-kV oil-break switch, type L42T, rated up to 750 MVA. Full description given in pamphlet No. 1273.

Lighting Fittings. HOLOPHANE LTD., Elverton-street London, S.W.1. "In-Bilt" fittings for ceiling lighting. Flush and projecting types. Illustrated brochure gives range and performance.

The Engineering Outlook—12

GENERAL AND CONSTRUCTIONAL ENGINEERING

DISTRIBUTING RISING INVESTMENTS TO ENSURE EXPORT MARKETS

This, the final article of the ENGINEERING Outlook series, provides an opportunity of drawing general conclusions about the prospects of the engineering industry as a whole as well as of discussing trends in some of the sections not so far covered. Two recent developments may perhaps be singled out as of outstanding importance: the rise in the bank rate and the agreement on engineer's wages. The former is perhaps mainly significant to the engineering industry as a timely reminder that prosperity cannot be based only upon a high volume of home sales. Increased production requires larger imports of raw materials, which can be paid for only by increased exports. Any unfavourable movement in the terms of trade, moreover, requires proportionately more exports to a given volume of imports. By the beginning of 1955, after a continuing drain on the foreign reserves, there was some evidence that the volume of exports was was not sufficiently large in relation to a volume of production, which in January was about 5 per cent. higher than a year before.

It now seems likely that the increase in bank rate to 4½ per cent. and the tightening up on hire-purchase terms will prove to have been adequate correctives. The immediate effect on demand in the home market has not perhaps been very considerable, but it has helped to establish confidence in the long-term stability of sterling among foreign holders who, impressed by the general effectiveness of British monetary policy in the past two or three years, are less inclined to part with it than in, say, the devaluation crisis of 1949. The fall in gold and dollar reserves has been to some extent due to falling prices in the United States at a time when British prices continued to rise, and this has been accepted as one of those temporary disparities which are bound to occur from time to time. Following the recent setback on Wall Street there is some anxiety about future trends in the United States, but the fall in share prices seems to have been due wholly to concern over such peculiarly stock-exchange matters as the amount of down-payment required when buying shares on credit. In any case, the experience of the first half of 1954 has largely allayed fears that a slump in the United States may be exported to the rest of the world: while in the spring of 1954 U.S. output had dropped by 10 per cent. from the peak of 1953, Sterling Area gold and dollar reserves continued to rise throughout the period.

While the present situation is healthy enough from the monetary point of view, it will only remain so if exports increase. It is no doubt possible, as Mr. R. A. Butler has said, that the standard of living may double in the next 25 years, but this does not mean that manufacturers of consumer goods are justified in undertaking expansion schemes with the sole object of doubling their home-market sales. Unfortunately, there seems to be insufficient emphasis on production for export in some of the programmes for expansion output of such engineering products as domestic electrical appliances and passenger cars. Admittedly, a high volume of home sales can secure economies of volume production which may greatly assist manufacturers to sell abroad against increasing competition. Car manufacturers, for example, may well maintain that in a dynamic industry such as theirs they could not even maintain the present volume of exports without a substantial increase in capacity which must be based very largely on home sales. If this is so, the increase in home market sales may have to be achieved at the expense of other forms of consumer outlay.

Greater efficiency may perhaps permit total consumer outlay to expand proportionately rather more than exports but exports must nevertheless increase substantially, and this increase will have to come to a large extent from the engineering industries, including the motor-vehicle and light-electrical industries. Exports of some traditional types of British manufactures, notably cheap cotton textiles, may be expected to continue to fall, and the United Kingdom can only pay its way in the world by concentrating more and more upon products in which the country's capital, technical knowledge and skill can be used to the full advantage.

CAPITAL AND LABOUR

In recent years, considerable concern has been expressed over the volume as well as the distribution of British capital investment. In aggregate, it does not, however, compare badly with what has been achieved in other countries. In the United States, it is true that each industrial worker has at his disposal three times as much power as his counterpart in the United Kingdom, but whereas the amount of capital per head in the United States is now only slightly higher than in 1929, investment in the United Kingdom has increased rapidly since 1948.

In a recent *Westminster Bank Review* Professor A. Cairncross estimates that net investment in 1953 accounted for about 10·8 per cent. of total net income compared with 8·1 per cent. in 1948 and 3·6 per cent. in 1938. Professor Cairncross cites an analysis by Mr. David Walker to show that despite the heavy weight of taxation, industry is setting aside more for expansion out of profits than before the war. In only one of 28 industries surveyed had there been a fall in the ratio of undistributed profits and depreciation to turnover, and the average for post war years (1948 and 1949) was 4·4 per cent. compared with 3·8 per cent. for 1936 to 1938. Professor Cairncross admits, however, that a comparatively small increase in savings and investment "rightly applied" could raise productivity substantially. The emphasis is on the distribution of investment, and, unfortunately, there is a danger that taxation by discouraging productive investment at the expense of government-sponsored social outlay may lead to a distortion of the pattern of investment.

The whole subject of investment is, however, fraught with difficulties and statistical approaches can be very misleading. Technical progress can enable a higher volume of output to be achieved for a considerably smaller investment in monetary terms than was formerly required. Commercial changes, on the other hand, can often greatly reduce the value of any particular investment within a very short space of time. Thus, without any really satisfactory way of measuring the quantity or quality of investment, it is possible to come to no better conclusion than that the "optimum" level of investment is the "maximum" possible. It is to be hoped that the accent in the coming Budget will again be on measures to encourage investment and raise productivity.

Some of the increase in productivity to be expected in the engineering industry has already been mortgaged in the recent rise in engineer's wages. The agreement on this occasion was reached with commendable promptness and the industry should be able to meet the increases (which amount to between 4 and 5 per cent. of the wages bill) without any serious inflation of costs and prices. Moreover, it is not necessarily a bad thing that the unions should press for higher wages: such pressure (provide demands are not excessive) can prove a useful stimulus to the pursuit of higher productivity. It is, however, disappointing that no agreement was reached on the principle of a wages structure for the engineering industry. The subject is difficult but a solution is long overdue, and with the rapid advance in production methods in the engineering industry, becomes yearly more urgent. The Unions had prepared a scheme under which, by the introduction of three or four grades for semi-skilled workers, wages might be more closely related to skill, and the employers had proposals of their own. It is unfortunate that both sides now seem to be agreed that only gradual improvement is possible.

MECHANICAL HANDLING AND EARTHMOVING PLANT

The rise in output of mechanical-handling plant, illustrated by the graphs of Fig. 1, herewith, provides some evidence of the pursuit of productivity in the United Kingdom. In most cases, exports fall off somewhat but with the exception of works trucks, output was nevertheless considerably higher in 1954 than in 1953. A further substantial increase is fairly well assured for this year when factory-building programmes are being accelerated and employers are faced with acute shortages of labour in many areas. In the export markets, competition, particularly in works trucks, is becoming steadily more formidable. Some companies are exporting as much as 40 per cent. of their output, but, in addition to the Americans, who have been long established in the market, a large number of European makers are now competing for the available business.

Output of civil engineering and contracting plant should also increase somewhat this year

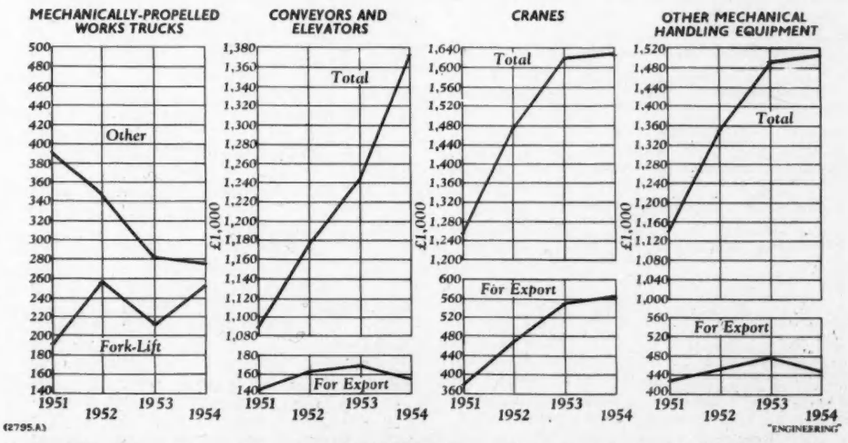

Fig. 1 Monthly average output of mechanical-handling equipment made in the United Kingdom during the past four years. Despite a slackening in exports, overall output has increased.

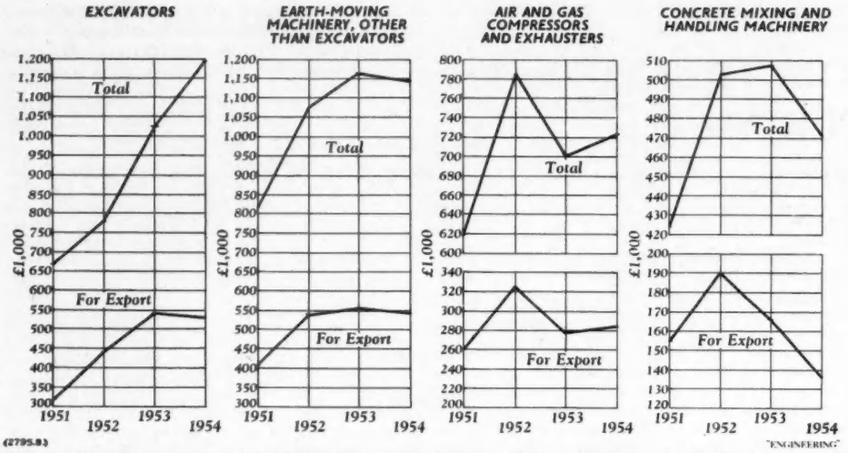

Fig. 2 Monthly average United Kingdom production of civil-engineering and contractors' plant. Output of this type of equipment is now more than 30 times the pre-war figure if parts and accessories are included.

in consequence of heavier expenditure on public works. Again, competition is increasing abroad, and (see Table I taken from *Trade and Navigation Accounts*, and Fig. 2) exports fell off slightly in 1954. Nevertheless, this branch of the engineering industry has made considerable progress. Before the war, output of earthmoving equipment in the United Kingdom amounted to only about £900,000 a year; it is now about £33 million per annum including parts and accessories. Some types of heavy excavators for use mainly in opencast mining have still to be imported from the United States but the United Kingdom is now self-sufficient in most types of earth-moving equipment. A high proportion of the equipment being made in the United Kingdom is basically of American design (manufactured either under licence, or by British subsidiaries of United States Companies) but many British manufacturers have also been willing to take the risk of bringing out original designs, and have succeeded in evolving machines which sell well in competition with the products of the long-established United States manufacturers. The lessons of American experience are valuable for almost all types of contractor's plant—and British manufacturers are not slow to learn them. American practice, for example, has shown the advantage of using larger tools with portable air compressors and also of providing a larger reserve of power to allow for increasing consumption of compressed air as tools become worn. British manufacturers, are now tending to increase their standard compressor sizes by about 20 per cent. Several are now working on rotary designs—which have been gaining ground in the United States—and some are already being marketed. It is still, however, too early to say to what extent these will supplant traditional reciprocating machines.

Constructional engineers are already benefiting from the larger factory and road-building programmes. Exports are still below the pre-war volume, and despite the rising costs of steel which continental competitors are having to meet, are not likely to improve much in the near future. The constructional branch of the engineering industry has perhaps been the least fortunate in its steel supplies. There has been a persistent shortage of certain joist sections and it has seldom been possible to obtain delivery of the different materials in the desired sequence so that the flow of work through the shops has been considerably retarded. The expansion programmes of the iron and steel industry should shortly, however, bring a return to pre-war efficiency. Despite progress in other forms of construction the use of steel is increasing. Steel-framed construction is still broadly accepted as being essential for the heavier industrial building, and for such buildings as large office blocks; due to the ease and speed of erection, it still compares very favourably in cost with other methods.

TABLE I.—UNITED KINGDOM: EXPORTS OF SOME INDUSTRIES, CLASSIFIED AS "GENERAL ENGINEERING."
(Value £1,000)

—	1950	1951	1952	1953	1954
Air and gas compressors and exhausters	3,824	4,353	5,284	4,986	5,157
Boot and shoe machinery	715	718	902	885	958
Cement-making machinery	1,693	1,506	1,796	1,445	995
Centrifugal drying machinery	401	566	769	817	709
Concrete-mixing machinery	1,013	1,182	1,389	1,301	1,116
Condensers	511	653	599	788	890
Cranes, hoists and other lifting machinery	3,284	8,751	10,754	12,234	11,765
Dairy machinery	1,828	1,915	1,883	1,122	1,378
Excavating and similar digging machinery	7,862	9,838	14,250	16,111	14,949
Fans (power-driven)	1,483	2,039	2,515	2,715	2,564
Food preparation and sterilising machinery	4,581	4,154	5,011	4,538	4,238
Furnace plant	1,304	1,070	1,518	1,473	1,417
Gas and chemical machinery	3,186	2,331	2,207	2,229	2,444
Grain-milling machinery	2,465	2,122	2,477	2,059	2,040
Hydraulic machinery	504	1,260	1,357	913	790
Laundering and dry-cleaning machinery	5,119	8,899	7,113	6,030	6,758
Lawn mowers	1,447	1,831	1,651	1,542	1,829
Office machinery	5,966	9,249	9,681	10,657	11,787
Packing, packeting and labelling machinery	2,797	3,117	3,386	2,883	3,514
Portable power tools	2,998	3,544	3,825	3,794	4,181
Printing and bookbinding machinery	10,001*	9,808*	9,300	8,509	9,061
Pulp and papermaking machinery	2,085	2,081	3,204	4,119	4,086
Pumps	8,326	9,776	13,299	13,496	13,234
Road rollers	1,200	1,077	1,570	1,610	1,658
Sewing machines and parts	5,999	7,024	8,315	7,297	8,048
Sugar-making and refinery machinery	2,363	2,327	2,819	2,426	3,667
Tobacco and cigarette-making machines	1,945	2,419	2,880	3,385	4,255
Weighing machinery	1,306	1,514	1,646	1,606	1,495
Welding machinery	2,420*	2,714*	2,365	2,421	1,791
Woodworking machinery	2,083	2,200	2,517	2,077	1,862
Ball and roller bearings	2,533	2,471	3,176	3,620	3,863
Ophthalmic instruments	565	854	648	698	796
Medical and surgical instruments	2,187*	2,491*	1,861	1,776	2,078
All other scientific instruments	6,850	7,807	9,243	9,968	11,023
Clocks and watches	1,376	1,348	1,123	1,050	1,342
Total	104,220	125,009	142,333	142,580	147,738

* Not comparable with figures for 1952, 1953 and 1954.

COMPUTERS AND OFFICE MACHINERY

The rapid pace of technical development in the instrument industry is one of the major sources of increased industrial productivity. Sir George Duncalfe, president of the British Standards Institution has spoken of this as creating "an industrial revolution greater than the world has yet seen." Work has already progressed beyond the stage of applying automatic control to an individual operation: a series of controlled operations can now be linked to a master electronic device which can control the movements of material from one process to the next with an accuracy of prediction and delicacy of judgment exceeding anything human control or judgment could achieve. The success of electronic equipment already being marketed is spectacular enough. The office-machinery industry, for example, is now offering electronic computers at prices which justify their use in the ordinary commercial office. Among the most recent is the HEC of the British Tabulating Machine Company which has a drum "memory" capable of storing 1,024 numbers and instructions, and the DEUCE of the English Electric Company, described in ENGINEERING for March 11. The latter, a binary digital machine, claimed to be the best of its type in Europe, has a recording drum capable of storing 8,192 words or over 250,000 digits. The cost of this machine is about £50,000. Elliott Brothers, Limited, are catering for the needs of occasional users who could not justify the purchase of an expensive computer by offering their "402" machine for hire at rates ranging from £25 to £35 per computer working hour. Computers are still the largest single project being undertaken by the National Research Development Corporation, who claim that although more money is being spent on research and development in this field in the United States, British engineers are still holding their own.

Output of the more traditional types of office machinery is continuing to increase (Fig. 3,) and in most cases reached record levels in 1954. Rapid expansion of British manufacturing capacity has greatly lessened the need for imports and a useful export market, reaching about £12 million in 1954, has also developed. Exports to the United States suffered a setback in 1954, and this is mainly responsible for the fall in exports of accounting machinery shown in the diagram, but they still amounted to £1·5 million. Although some manufacturers are frustrated through shortage of suitable labour, the industry is still extending its capacity. Even so, they are scarcely keeping pace with the growth in demand. In particular, there is considerable scope for increased sales of typewriters in the United Kingdom where the number per head of population is much less than in the United States. Electric typewriters are likely to establish themselves quickly as standard office equipment: in the United States they account for probably as much as 17 per cent. of the total number in office use. In the United Kingdom, only two companies, International Business Machines, Limited (who do not manufacture non-electric machines here) and Underwood Machines, Limited, are making electric typewriters, but others are understood to be considering their production.

CLOCKS AND WATCHES

The manufacture of clocks and watches is another industry which has been making rapid strides. The absence of German competition in the immediate post-war years gave the industry the opportunity to become firmly established. By 1951, when German competition had again begun to revive, the British clock manufacturers, highly mechanised and with well-organised production lines, were in a position to counter it. The threat is, however, increasing. In Germany, the execution of a certain amount of

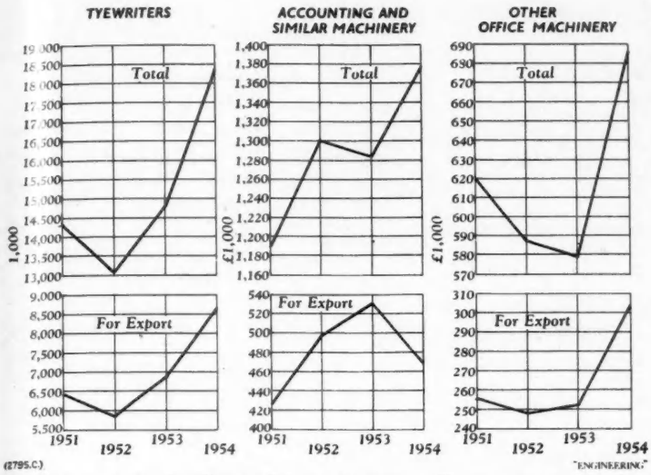

Fig. 3 Office equipment in the United Kingdom since 1951; the figures are monthly average outputs. In general there were marked increases in output during 1954.

assembly work by families at home cuts overheads, and with the advantage of lower wages and longer working hours, the Germans are gaining ground in export markets. An import tariff of 25 per cent., moreover, may give little protection in the home market against German manufacturers whose exports are subsidised. Nevertheless, the healthy state of the industry is clearly shown in the rising graphs of Fig. 4.

The volume of British output of high-quality fully-jewelled lever watches which can compete with Swiss products, although growing, is still comparatively small. In view of the special advantage in skill and specialised machinery possessed by the Swiss, it is probably undesirable as well as impracticable to compete with them on any scale. This view has not, however, prevailed in the United States. On the advice of the Tariff Commission, the Administration increased the import duty on watches in July, 1954, by

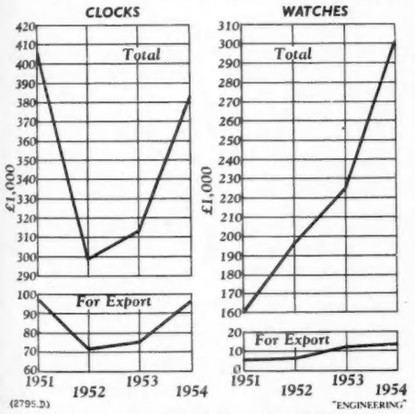

Fig. 4 Clocks and watches. Monthly average outputs in the United Kingdom since 1951.

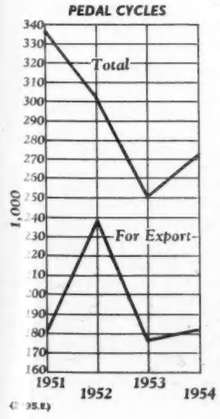

Fig. 5 Monthly average outputs of pedal cycles since 1951 in the United Kingdom. The dollar areas continue to be the largest market for British cycles.

50 per cent. with the ostensible purpose of protecting the home industry in the interests of national defence. In October, when the Department of Justice filed an anti-trust suit against 24 watch manufacturers (including six of Swiss origin) the Swiss regarded this as "the second step in a careful pattern designed to cripple the Swiss watch industry." This is no doubt unfair, but the Swiss, whose trade has suffered a considerable setback, can perhaps be forgiven for their uncharitable interpretation.

RECOVERY IN BICYCLE OUTPUT

A major British exporting industry which may suffer from U.S. import restrictions is the manufacture of cycles. The United States is at present by far the biggest market for British bicycles, taking 534,200 machines in 1954 out of total exports of 2 million. The increase in British exports has been accompanied by a sharp decline to the sales of the U.S. manufacturers who complain that imported cycles, which represented only 1·38 per cent. of the market in the years 1946 to 1949, now account for 35·87 per cent., and that their own sales in 1954 have been about 40 per cent. lower than in 1953. Application was made to the Tariff Commission for increased protection in order to prevent foreign manufacturers "from abusing our generosity to the extent of destroying industries," and, after a sympathetic hearing, the Board have recommended the Administration to take action. The latter are committed to the pursuit of liberal trade policies and are seeking at present a three-year extension of the Reciprocal Trade Agreements Act. This contains an "escape" clause (designed to give protection where foreign infiltration may have serious consequences) under which the bicycle manufacturers are now appealing. Opponents of the extension of the Act claim that recommendations of the Tariff Commission for protection under this clause are almost invariably turned down by the Administration. Their case will be greatly strengthened if no concessions are made to the bicycle makers, and the Administration may have great difficulty in passing the Reciprocal Trade Act Extension Bill.

Prospects for cycle manufacturers on the British home market and in some of the other export markets are now better than they have been since 1951. As may be seen from Fig. 5, left, total output of bicycles has already recovered considerably in 1954, and the upward trend is continuing. Output of motor cycles in 1954, was a record of 180,000 machines.

To sum up briefly on the prospects of the engineering industry as a whole: most sections can look forward to increasing activity. This is based perhaps rather too much on home market sales, but recent Government monetary control measures should be enough to correct any excess in home demand. Increased investment of the right sort should raise productivity, keep British products competitive in export markets and yield a higher standard of living for the British people. It is to be hoped that the coming Budget will make further provision for improving investment—perhaps by adjusting depreciation allowances.

* * *

PRODUCTION OF TITANIUM POWDER IN THE LABORATORY

Considerable research and development work has been carried out in recent years on the metallurgy of titanium and titanium alloys. Much of this effort has been expended on studies of extraction and refining processes, since titanium is still relatively costly to produce as a pure metal. Until their prices have been brought down by lower manufacturing costs and increased production, titanium-base materials are not likely to find the widespread uses that their properties appear to merit.

Of the manufacturing processes available for titanium and its alloys, melting and casting have naturally received most attention. At such a comparatively early stage in the development of new materials, however, it is important to examine possible alternative methods one of which is by powder metallurgy.

Among the difficulties associated with the powder metallurgy of titanium is that of obtaining the finely-divided powder uncontaminated with oxygen or nitrogen. Pure titanium sponge, obtained by reduction of the tetrachloride by magnesium, is too malleable to be crushed into powder by virtue of its very freedom from these embrittling elements. On the other hand, titanium powder produced by the reduction process is found to give rise to hard, brittle compacts after sintering *in vacuo*, owing to the presence of oxygen and nitrogen in the powder.

A method developed at the research laboratories of the General Electric Company, Limited, enables small quantities of titanium or titanium hydride to be produced in finely-divided form and substantially free from oxygen and nitrogen. The process consists of embrittling pure titanium sponge with hydrogen under carefully-controlled conditions. The titanium hydride can then be sintered as such, hydrogen being evolved during the sintering process. Alternatively, the hydrogen can be removed by a separate vacuum treatment at temperatures up to 800 deg. C. to leave fine titanium powder.

The titanium sponge used as a starting material is selected on the basis of the hardness of a small sample prepared by arc-melting. This should be less than 200 diamond-pyramid numbers. The sponge is first activated by a short treatment of about 5 minutes at 700 deg. C. under a vacuum of 10^{-5} of mercury. It is then allowed to cool to 450 deg. C., and specially-purified hydrogen is admitted to the reaction chamber. After hydrogenation of the sponge, the apparatus is cooled to room temperature under a static pressure of hydrogen.

The most convenient method of purifying the hydrogen has been found to be to bubble the gas through molten magnesium. Although the magnesium is maintained just above its melting point, at 675 deg. to 725 deg. C., a glass-wool scrubber is necessary to prevent magnesium vapour from being carried over by the hydrogen into the reaction chamber. The titanium hydride prepared thus usually contains from 3 to 4 per cent. hydrogen by weight, and is shown by X-ray analysis to have single-phase crystal structure approximating to the face-centred cubic.

The hydrogenated sponge after grinding can be satisfactorily pressed and vacuum-sintered to give hardness values of less than 200 D.P.N., provided that the powder is screened and the very fine (below 300 mesh) fraction removed. This powder is naturally very reactive, owing to its large surface area, and becomes superficially contaminated during grinding. The remaining hydride powder is quite stable over long periods and can be used as a base material for the preparation of massive titanium or titanium alloys by powder-metallurgical methods.

THE ENERGY THEOREMS OF STRUCTURAL ANALYSIS

3—WORKED EXAMPLES

By E. H. Brown, PH.D., B.SC.(ENG.), D.I.C.*

The first two parts of this article, "Definitions and Fundamentals" and "Derivation and Discussion of the Theorems," were published in our issues of March 11 and March 18, respectively. This third and concluding article illustrates the use of the nine energy theorems by eleven worked examples.

It is impossible in so few examples as follow to show the full scope of the theorems that were derived and discussed in Part 2, page 339. Most of the problems have been chosen rather for brevity: in this way the structure of the solutions —expression of energy in an appropriate form, application of the theorem, derivation of the result—is not submerged in a welter of mathematics.

In practice, solutions are often possible by alternative theorems; there is skill required in choosing the best theorem, and the best choice for one solution may be no guide to the next. Two such alternatives, leading to completely different calculations, are illustrated among the examples which follow.

Notation.—The following additional notation is used in Part 3 :

E, Young's modulus;
G, shear modulus;
ν, Poisson's ratio;
B, C, c_1, c_2, other elastic constants;
A, cross-sectional area of a member of a structure;
I, second moment of area;
J, polar second moment of area;
a, edge length of a square plate;
d, rise of an arch;
h, thickness of a thin plate;
L, a length;
u, horizontal displacement;
v, vertical displacement;
w, transverse displacement of a plate;
H, horizontal force;
V, vertical reaction;
W, vertical force;
M, bending moment;
T, force in a member of a structure; or torque; and

$$D = \frac{E h^3}{12 (1 - \nu^2)}.$$

Suffixes will be added or removed from previously defined notation, as may be convenient. In any particular example this should provoke no confusion.

Example 1.—A 5-ft. high 8-in. by 8-in. wooden post is built in at its base and supported at the top by five steel guys each of 0·1 sq. in. cross-sectional area. The guys are inclined at 30 deg. to the horizontal, are initially unstressed, and are arranged in plan as shown in Fig. 9. It is required to find the load in the central guy when a horizontal load of 2 tons is applied at the top of the post, as shown in the figure. E for steel, 30×10^6 lb. per square inch, for the post $1{\cdot}5 \times 10^6$ lb. per square inch.

By symmetry, the only movement of the top of the post will be in the direction of the load; denote this displacement by Δ. The extension of a guy $= e = \Delta \cos 30 \cos \alpha$ where α is the appropriate angle shown in Fig. 9. The strain energy of a guy is

$$\iiint \left\{ \int \sigma \, d\epsilon \right\} dx \, dy \, dz = \frac{E \epsilon^2}{2} \times A L_g$$

where L_g is the length of each guy, and A its cross-sectional area. Since $\epsilon = \frac{e}{L}$, the energy is $\frac{A E e^2}{2 L_g}$.

The energy of the post is $\frac{1}{2} \Delta$ multiplied by the load taken by the post. The deflection of such a cantilever is $\frac{P L^3}{3 E I}$, so that $P = \frac{3 E I \Delta}{L^3}$, and the energy is $\frac{3 E I \Delta^2}{2 L^3}$, where L is the length of the post.

Giving e its value of $\Delta \cos 30 \cos \alpha$, the total strain energy is

$$U = \frac{A E_s}{2 L_g} \Delta^2 \cos^2 30 \{1 + 2 \cos^2 22\tfrac{1}{2} + 2 \cos^2 45\} + \frac{3 E_p I \Delta^2}{2 L^3}.$$

This is the required form for U in terms of the displacement Δ, without involving any forces, internal or external. Inserting the numerical values, $L = 60$ in., $L_g = \frac{60}{\sin 30} = 120$ in.,

$$U = 3{\cdot}83 \times 10^4 \, \Delta^2 \text{ lb. in.}$$

Applying Castigliano's equilibrium theorem,

$$\frac{\partial U}{\partial \Delta} = 7{\cdot}66 \times 10^4 \, \Delta = 2 \text{ tons.}$$

The load taken by the central guy $= T_0$, where

$$T_0 = \frac{A E_s}{L_g} e = \frac{0{\cdot}1 \times 30 \times 10^6 \times \Delta \cos 30}{120}$$

i.e., $T_0 = 0{\cdot}566$ tons.

The problems of cable bracing are considered at greater length by Pippard[11] who uses an ingenious method to reduce the number of internal redundant forces, and solves by the theorem of least work.

Example 2.—The pin-jointed truss of Fig. 10, loaded as shown, has eccentrically loaded compression members, A B, B C and C D, whose load/extension relation is $T = \frac{B e}{L} + C e^2$; for the remaining members $T = \frac{A E e}{L}$. Find the vertical deflection at E.

Let u denote a horizontal and v a vertical displacement, positive to the right and downwards respectively. Then $v_A = v_D = 0$, and we may take $u_E = 0$, allowing horizontal movements at both A and D. From symmetry,

$$u_A = -u_D, \quad u_B = -u_C, \quad v_B = v_C.$$

By taking components of the displacements in the directions of members we find the extensions:—

Members

AB, CD: $\frac{1}{2}(u_D - u_C) - v_C \frac{\sqrt{3}}{2} = e_1$, say;

BC: $2 u_C = e_2$;

BE, CE: $\frac{u_C}{2} + (v_E - v_C) \frac{\sqrt{3}}{2} = e_3$;

AE, DE: $u_D = e_4$.

These expressions give the required displacement as

$$v_E = \frac{1}{\sqrt{3}} \{e_4 + 2 e_2 - e_3 - 2 e_1\}. \quad (19)$$

We now apply an arbitrary small displacement at all the joints, preserving the symmetry, and apply the theorem of virtual work:

$$dU = W \, dv_E.$$

Alternatively we can apply the theorem to each member in turn and add the results, giving $dU = \Sigma T \, de$.;

$$\Sigma T \, de = \frac{W}{\sqrt{3}} \{de_4 + 2 \, de_3 - de_2 - 2 \, de_1\}. \quad . \quad . \quad . \quad (20)$$

As the displacements, and hence the extensions, were arbitrary this equation can only hold if the coefficient of each small displacement is the same on both sides of the equation. This results in four independent equations, and by expressing the forces T in terms of the extensions and solving we find

$$e_1 = e_2 = -\frac{B}{2CL} + \sqrt{\left\{\left(\frac{B^2}{4C^2L^2}\right) - \left(\frac{W}{C\sqrt{3}}\right)\right\}};$$

$$e_3 = \frac{WL}{AE\sqrt{3}}; \quad e_4 = \frac{WL}{2AE\sqrt{3}}.$$

Substituting in equation (19) we obtain the result,

$$v_E = \frac{5WL}{6AE} + \frac{B\sqrt{3}}{2CL} - \sqrt{\left\{\frac{3B^2}{4C^2L^2} - \frac{W\sqrt{3}}{C}\right\}}.$$

Example 3.—A 30-ft. long steel beam (Fig. 11) rests on three supports A, B, and C, which yield respectively 0·05 in., 0·10 in., and 0·04 in. per ton of load upon them. $E = 30 \times 10^6$ lb. per square inch, $I = 350$ in.^{4} A second beam rests upon the first immediately above the support B, so that the first beam forms one of the supports to the second, of amount P. If the support B were unyielding the force P would be 15 tons, but it diminishes 6·6 tons per inch of the deflection at B. Find the force P.

Let Δ_1, Δ_2, and Δ_3 denote the deflections at A, B and C respectively. The yielding supports may be considered as springs of stiffnesses k tons per inch, and each will store an appropriate amount of energy $\frac{1}{2} k \Delta^2$.

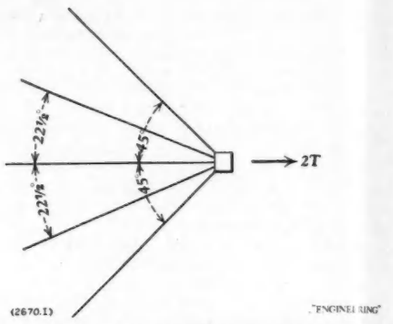

Fig. 9 Example 1: A cantilevered post, tied back by five steel guys, resists a horizontal pull of 2 tons. The load in the guys may be found by using Castigliano's equilibrium theorem, expressing all the conditions in terms of the displacement at the top of the post.

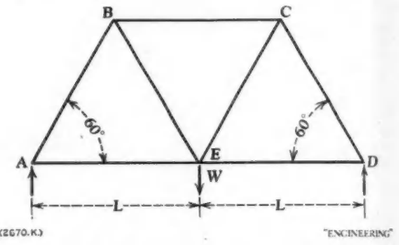

Fig. 10 Example 2: A pin-jointed frame with eccentrically-loaded compression members, giving non-linear load/extension relations. The vertical deflection at E can be found by the theorem of virtual work.

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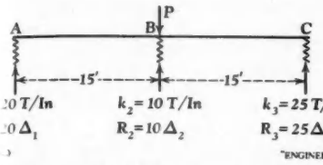

Fig. 11 Example 3: The beam ABC is typical of a member of a grillage system, with the force P dependent on the amount of deflection at B. For given conditions of yield in the supports the theorem of minimum potential energy can be used to evaluate P.

The beam may be considered as simply-supported at A and C, with a central point load giving a deflection at B of $\Delta_2 - \frac{\Delta_1 + \Delta_3}{2}$ which is $\frac{W L^3}{48 E I}$, where W is the part of P carried by the beam to A and C. Then $W = \frac{48 E I}{L^3}\left(\Delta_2 - \frac{\Delta_1 + \Delta_3}{2}\right)$, and the strain energy of the beam is $\frac{k_B}{2}\left(\Delta_2 - \frac{\Delta_1 + \Delta_3}{2}\right)^2$, where $k_B = \frac{48 E I}{L^3} = 4{\cdot}8$ tons per inch.

$$U = \tfrac{1}{2}\sum_{r=1}^{r=3} k_r \Delta_r^2 + \frac{k_B}{2}\left(\Delta_2 - \frac{\Delta_1 + \Delta_3}{2}\right)^2. \quad . \quad . \quad . \quad (21)$$

The force $P = 15 - 6{\cdot}6\ \Delta_2$, and its potential energy is thus

$$V = V_0 - \int_0^{\Delta_2} (15 - 6{\cdot}6\ \delta_2)\, d\delta_2$$
$$= V_0 - 15\ \Delta_2 + 3{\cdot}3\ \Delta_2^2. \quad . \quad (22)$$

Equations (21) and (22) give the strain and potential energies in terms of the displacements of certain points of the structure, and we may therefore apply the theorem of minimum total potential energy:

$$\frac{\partial}{\partial \Delta_1}(U + V) = k_1 \Delta_1 - \frac{k_B}{2}\left(\Delta_2 - \frac{\Delta_1 + \Delta_3}{2}\right) = 0,$$

$$\frac{\partial}{\partial \Delta_2}(U + V) = k_2 \Delta_2 + k_B\left(\Delta_2 - \frac{\Delta_1 + \Delta_3}{2}\right) - 15 + 6{\cdot}6\ \Delta_2 = 0,$$

$$\frac{\partial}{\partial \Delta_3}(U + V) = k_3 \Delta_3 - \frac{k_B}{2}\left(\Delta_2 - \frac{\Delta_1 + \Delta_3}{2}\right) = 0.$$

Δ_1 and Δ_3 may be eliminated between these three equations, to give

$$\Delta_2 = \frac{15}{k_2 + 6{\cdot}6}\left\{1 - \frac{4}{4 + (k_2 + 6{\cdot}6)\left(\frac{4}{k_B} + \frac{1}{k_1} + \frac{1}{k_3}\right)}\right\}$$
$$= 0{\cdot}713 \text{ in.}$$

Then

$$P = 15 - 6{\cdot}6\ \Delta_2 = 10{\cdot}2 \text{ tons.}$$

Example 4.—An alternative solution to the problem of example 2 is as follows. As was shown in example 2, the extensions of the members are linear functions of the displacements, so that superposition holds between displacements and extensions. Thus (cf. Part 1, "Expressions for Complementary Energy"—page 307) the problem is suitable for solution by complementary energy.

We first find the forces in all the members; in the present simple example this can be done by inspection and the values obtained are shown in Fig. 12.

$$S = \sum_n \int_0^{T_n} e_n\, dT_n \quad . \quad (23)$$

where the summation is over all the members of the frame.

For the tension members

$$e_n = \frac{T_n L}{A E};$$

for the compression members

$$e_n = -\frac{B}{2CL} + \sqrt{\left(\frac{B^2}{4C^2L^2} + \frac{T_n}{C}\right)}. \quad . \quad .$$

Integrating these expressions with respect to T_n and then substituting for the forces T_n in terms of W we find from equation (23),

$$S = \frac{L}{2AE}\left\{2 \times \frac{W^2}{12} + 2 \times \frac{W^2}{3}\right\} + 3\left\{\frac{BW}{2CL\sqrt{3}} + \frac{2C}{3}\left(\frac{B^2}{4C^2L^2} - \frac{W}{C\sqrt{3}}\right)^{\frac{3}{2}}\right\}. \quad . \quad . \quad . \quad (24)$$

This is the required expression for S in terms of the external load W. The first theorem of complementary energy now gives

$$\Delta = \frac{\partial S}{\partial W} = \frac{5WL}{6AE} + \frac{B\sqrt{3}}{2CL} - \sqrt{\left(\frac{3B^2}{4C^2L^2} - \frac{W\sqrt{3}}{C}\right)}.$$

Example 5.—A parabolic arch rib A B has a maximum rise d and a span L, and it is pinned at A and on rollers at B. Its cross-section varies in such a way that $I = I_0 \sec \alpha$, where α is the inclination of the rib to the horizontal (see Fig. 13). It is required to find the horizontal movement at B due to a central vertical load W.

Introduce a fictitious load H at B in the direction of the required displacement, balancing it by the statically-determinate supports. In this problem the three statically-determinate supports are the vertical force at B and the horizontal and vertical components of the force at A, and *the first task is to express them in terms of W and H* (see Fig. 13).

$I = I_0 \sec \alpha = I_0 \frac{ds}{dx}$ (s is measured round the arch); also the arch and its loading are symmetrical. So we may write

$$U = \int_A^B \frac{M^2\, ds}{2EI} = \int_0^L \frac{M^2\, dx}{2EI_0}$$
$$= 2\int_0^{\frac{L}{2}} \frac{M^2\, dx}{2EI_0}.$$

From

$$x = 0 \text{ to } x = \frac{L}{2}, \quad M = -\left(\frac{Wx}{2} + Hy\right);$$

hence

$$U = \frac{1}{EI_0}\int_0^{\frac{L}{2}} \left(\frac{Wx}{2} + Hy\right)^2 dx. \quad (25)$$

For a parabolic arch $y = 4dx\left(\frac{L - x}{L^2}\right)$, and substituting this in equation (25) we could evaluate the integral and arrive at an expression for U in terms of the external loads, as required for the use of Castigliano's theorem for linear structures. However, equation (25) as it stands is in terms of the external loads, and the work is considerably simplified by differentiating according to the theorem before evaluating the integral. The horizontal movement at B is Δ, where

$$\Delta = \frac{\partial U}{\partial H} = \frac{1}{EI_0}\int_0^{\frac{L}{2}} 2y\left(\frac{Wx}{2} + Hy\right) dx.$$

It is now convenient to recall that H is a fictitious load which should be zero:

$$\Delta = \frac{W}{EI_0}\int_0^{\frac{L}{2}} xy\, dx$$
$$= \frac{W}{EI_0}\int_0^{\frac{L}{2}} \frac{4d}{L^2} x^2 (L - x)\, dx$$
$$= \frac{5WL^3 d}{48 E I_0}.$$

Example 6.—A thin square plate has all its edges encastré, and carries a central transverse point load. Find the bending moment per unit length at the middle of each side if the deflection under the load is one-tenth of the plate thickness.

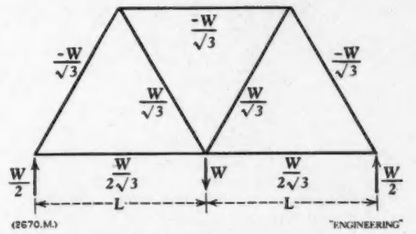

Fig. 12 Example 4: The frame of Fig. 10, showing the forces in the members (tensions considered as positive). The extensions are linear functions of the displacements, although not of the forces, so that an alternative solution is possible by complementary energy.

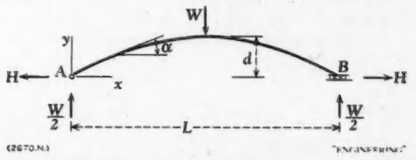

Fig. 13 Example 5: Castigliano's theorem for linear structures is used to find the horizontal movement at B due to the central point load W only.

On the assumption that lines initially straight and normal to the middle surface of the plate remain so after the load has been applied, the strain energy expression may be developed from equation (1′) to the form

$$U = \frac{D}{2}\int_0^a \int_0^a \left\{\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right)^2 - 2(1 - \nu)\left(\frac{\partial^2 w}{\partial x^2}\frac{\partial^2 w}{\partial y^2} - \left(\frac{\partial^2 w}{\partial x\, \partial y}\right)^2\right)\right\} dx\, dy$$

where

$$D = \frac{E h^3}{12(1 - \nu^2)}.$$

(See, for example, reference 12, page 50.)

As $w = 0$ on all the edges of the plate, this expression may be simplified* to

$$U = \frac{D}{2}\int_0^a \int_0^a \left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2}\right)^2 dx\, dy.$$

An approximate solution may be found by assuming a deflected shape for the middle surface in the form

$$w = \sum_{n=1}^{\infty} a_n \left(1 - \cos\frac{2\pi n x}{a}\right)\left(1 - \cos\frac{2\pi n y}{a}\right),$$

where a_n represents unspecified constants.

The boundary conditions are $w = 0$ when $x = 0, a$ or $y = 0, a$; $\frac{\partial w}{\partial x} = 0$ when $x = 0, a$; $\frac{\partial w}{\partial y} = 0$ when $y = 0, a$; they are satisfied by our expression for w whatever the values of the

---

* Writing $\frac{\partial^2 w}{\partial x^2} = w_{xx}$, etc., we find

$$2\iint (w_{xx} w_{yy} - w^2_{xy})\, dx\, dy$$
$$= \iint \left\{\frac{\partial}{\partial x}(w_x w_{yy} - w_y w_{xy}) + \frac{\partial}{\partial y}(w_y w_{xx} - w_x w_{xy})\right\} dx\, dy$$
$$= \oint [(w_x w_{yy} - w_y w_{xy})\, dy + (w_y w_{xx} - w_x w_{xy})\, dx]$$
$$= \oint \left[\left\{2 w w_{xyy} - \frac{\partial}{\partial y}(2 w w_{xy} - w_x w_y)\right\} dy + \left\{2 w w_{xxy} - \frac{\partial}{\partial x}(2 w w_{xy} - w_x w_y)\right\} dx\right]$$
$$= 0,$$

for w is zero on the boundary of the plate, and its derivatives are all continuous.

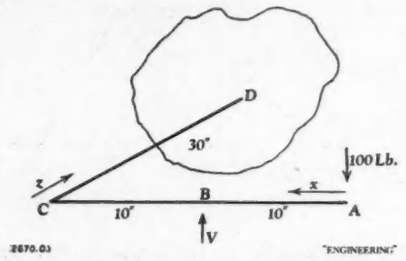

Fig. 14 Example 7: An L-shaped bar is fixed in the wall at D, and in addition is simply-supported at B. The reaction at B for a given load at the end A can be found by the second theorem of minimum strain energy.

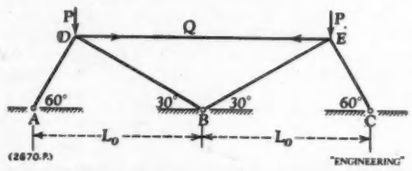

Fig. 15 Examples 8 to 11: The force in member DE of this pin-jointed frame is found by the theorem of least work, allowing for any initial lack of fit in DE. The solution is repeated by the second theorem of complementary energy, to take account of initial curvature in members AD and CE.

constants a_n. The solution will only be an approximate one, for the single infinity of constants a_n is not sufficient to give any deflection shape; but the form for w seems intuitively a good one, and a fairly accurate result may be expected.

Substituting for w in the strain energy expression gives

$$U = \left(\frac{16\pi^4 D}{a^2}\right) \sum_{n=1}^{\infty} n^4 a_n^2.$$

Before using the energy theorem we must restrict w to give the specified displacement. When $x = y = \frac{a}{2}$

$$w = \frac{h}{10} = \sum_{n=1}^{\infty} a_n (1 - \cos n\pi)^2$$

$$= 4 \sum_{n=1, 3, 5, \ldots}^{\infty} a_n$$

$$a_1 = \frac{h}{40} - \sum_{n=3, 5, \ldots}^{\infty} a_n.$$

$$U = \left(\frac{16\pi^4 D}{a^2}\right)\left\{\left(\frac{h}{40} - \sum_{n=3, 5, \ldots}^{\infty} a_n\right)^2 + \sum_{n=2}^{\infty} n^4 a_n^2\right\} \quad . \quad . \quad . \quad (26)$$

This is the required expression for the strain energy, allowing an infinite choice of displacement configurations subject to the specified central displacement. Then by the first minimum strain energy theorem in its extended form, all the other constants a_n must take such values as will make U a minimum. There results an infinity of simultaneous equations $\frac{\partial U}{\partial a_i} = 0$ $(i = 2, 3, 4, \ldots)$, as follows :—

$$i \text{ even } \frac{\partial U}{\partial a_i} = \left(\frac{16\pi^4 D}{a^2}\right) 2 i^4 a_i = 0,$$

$$a_i = 0, \quad i \text{ even};$$

and i odd $\quad \frac{\partial U}{\partial a_i} = \left(\frac{16\pi^4 D}{a^2}\right)\left\{2 i^4 a_i - 2\left(\frac{h}{40} - \sum_{n=3, 5, \ldots}^{\infty} a_n\right)\right\} = 0,$

i.e., $$i^4 a_i + \sum_{n=3, 5, \ldots}^{\infty} a_n = \frac{h}{40},$$

where $i = 3, 5, 7, \ldots$

The first few of these simultaneous equations can be solved numerically and we find

$$a_3 = 0{\cdot}000304\,h, \qquad a_5 = 0{\cdot}0000395\,h,$$
$$a_7 = 0{\cdot}0000103\,h,$$

so that $a_1 = 0{\cdot}02464\,h$, and the series converges satisfactorily.

When $x = 0$ and $y = \frac{1}{2}a$, the bending moment per unit length is

$$M_x = D\left(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2}\right) = \frac{8\pi^2 D}{a^2} \sum_{n=1}^{\infty} n^2 a_n,$$

$$= 0{\cdot}213 \frac{E h^4}{a^2}.$$

The accurate solution (given in Timoschenko,[12] page 232) is $0{\cdot}206 \frac{E h^4}{a^2}$, so that our approximation gives an error of less than 4 per cent.

Example 7.—The L-shaped steel bar of Fig. 14 has a constant circular cross-section and lies in a horizontal plane. It is restrained against all movement or rotation at D and against vertical movement at B. Find the force at B when a load of 100 lb. is hung at A.

Neglecting the very small contribution from bending shear we may develop the strain energy due to bending and torsion from equation (1′)

$$U = \int_A^B + \int_B^C \frac{M^2}{2EI} dx + \int_C^D \frac{M^2}{2EI} dz + \int_C^D \frac{T^2}{2GJ} dz.$$

Denote the support at B by V; then

from A to B, $M = 100x$
B to C, $M = 100x - V(x - 10)$
C to D, $M = (100 - V)z$
C to D, $T = 2{,}000 - 10\,V.$

Then

$$U = \int_0^{10} \frac{10{,}000\,x^2}{2EI} dx + \int_{10}^{20} \frac{\{100x - V(x-10)\}^2}{2EI} dx + \int_0^{30} \frac{(100-V)^2 z^2}{2EI} dz + \int_0^{30} \frac{(2{,}000 - 10V)^2}{2GJ} dz. \quad . \quad (27)$$

This is the required expression for U in terms of the specified external loads and the redundant support V. (Note that all six of the statically-determinate supports are at D, and have not appeared in equation (27).) By the second theorem of minimum strain energy V must take such a value as will make this expression a minimum. Once again, it is more convenient to differentiate before integrating, thus

$$\frac{\partial U}{\partial V} = 0 = -\int_{10}^{20} \frac{(x-10)\{100x - V(x-10)\}}{EI} dx - \int_0^{30} \frac{(100-V)z^2}{EI} dz - 10\int_0^{30} \frac{(2{,}000 - 10V)}{GJ} dz.$$

For a circular cross-section, $J = 2I$, and for steel $G \doteq \frac{3}{8} E$. Then when the integrals are evaluated it is found that

$$V = 133 \text{ lb.}$$

Example 8.—All the members of the pin-jointed frame of Fig. 15 have the same cross-sectional area A, and a linear load/extension relationship. It is required to find the force in member DE due to the loading shown if there is no initial self-straining.

The frame has only one redundancy, which can be taken as Q, the required force in DE. The forces in the other members can be found in terms of P and Q by resolution

$$T_{AD} = T_{CE} = \tfrac{1}{2}(Q - P\sqrt{3})$$
$$T_{BD} = T_{BE} = -\tfrac{1}{2}(Q\sqrt{3} + P).$$

The strain energy is entirely due to the direct forces in the members, so equation (1′) gives the strain energy for each member as

$$U = \tfrac{1}{2}\iiint \sigma\epsilon\, dx\, dy\, dz = \frac{E}{2}\iiint \left(\frac{T}{AE}\right)^2 dx\, dy\, dz = \frac{T^2 L}{2AE}.$$

The lengths of the members are

$$L_{AD} = L_{CE} = \tfrac{1}{2} L_0$$
$$L_{BD} = L_{BE} = \tfrac{1}{2}(L_0\sqrt{3})$$
$$L_{DE} = \tfrac{3}{8} L_0.$$

Thus the total strain energy is

$$U = \Sigma \frac{T^2 L}{2AE}$$
$$= \frac{1}{2AE}\left\{\frac{2(Q - P\sqrt{3})^2}{4}\frac{L_0}{2} + \frac{2(Q\sqrt{3} + P)^2}{4}\frac{L_0\sqrt{3}}{2} + Q^2\frac{3L_0}{2}\right\}$$
$$= \frac{L_0}{8AE}\{(7 + 3\sqrt{3})Q^2 + 2(3 - \sqrt{3})PQ + (3 + \sqrt{3})P^2\}. \quad . \quad . \quad . \quad (28)$$

This is the required expression for U in terms of the external loads and Q. Equilibrium, both internal and external, has been satisfied, and the theorem of least work will give the condition for compatibility of the displacements. The theorem, in its first form, gives $\frac{\partial U}{\partial Q} = 0$:

$$\frac{L_0}{8AE}\{2(7 + 3\sqrt{3})Q + 2(3 - \sqrt{3})P\} = 0$$

$$Q = -\frac{(3 - \sqrt{3})P}{7 + 3\sqrt{3}}.$$

Example 9.—Find the force in member DE of the previous example if the member was initially λ short and had to be forced to fit the frame.

As all the load/extension relationships are linear we may consider this self-straining effect separately from the effect of the loads P. The strain energy of self-straining is then found by putting $P = 0$ in equation (28):

$$U_0 = \frac{(7 + 3\sqrt{3})L_0 Q^2}{8AE}. \quad . \quad (29)$$

Then the extension of the theorem of least work for self-strained structures gives

$$\frac{\partial U_0}{\partial Q} = \lambda = \frac{(7 + 3\sqrt{3})L_0 Q}{4AE}$$

or

$$Q = \frac{4AE\lambda}{(7 + 3\sqrt{3})L_0}.$$

The total force in DE is given by adding this result to the previous one:

$$Q = \frac{4AE\lambda - (3 - \sqrt{3})PL_0}{(7 + 3\sqrt{3})L_0}.$$

Example 10.—Repeat example 8, taking account of initial curvature in members AD and CE, giving extensions $e = c_1 TL + c_2 T^2 L^3$.

The extensions of the members are linear functions of the displacements (cf. example 4) so that superposition holds between displacements and extensions and the problem may be solved by complementary energy.

The expressions for the forces in the members, in terms of P and Q, are the same as in example 8, for they were found so as to satisfy equilibrium. The complementary energy is

$$S = \Sigma \int_0^{T_n} e_n\, dT_n, \quad . \quad . \quad (30)$$

where the summation is over all the members of the frame.

Members AD and CE each contribute

$$\int_0^T (c_1 TL + c_2 T^2 L^3)\, dT = \frac{c_1 T^2 L}{2} + \frac{c_2 T^3 L^3}{3}$$

and the other members each contribute

$$\int_0^T \frac{TL}{AE}\,dT = \frac{T^2 L}{2AE}.$$

Substituting for the forces T in terms of P and Q,

$$S = 2\left\{\frac{c_1}{2}\frac{(Q - P\sqrt{3})^2}{4}\frac{L_0}{2} + \frac{c_2}{3}\frac{(Q - P\sqrt{3})^3}{8}\frac{L_0^3}{8}\right\} + 2 \times \frac{(Q\sqrt{3} + P)^2 L_0\sqrt{3}}{16AE} + \frac{3Q^2 L_0}{4AE}. \quad . \quad . \quad . \quad . \quad (31)$$

This is the required expression for S in terms of the external loads and Q. Then the second theorem of complementary energy asserts that $\frac{\partial S}{\partial Q} = 0$; therefore

$$\frac{c_1 L_0}{4}(Q - P\sqrt{3}) + \frac{c_2 L_0^3}{32}(Q - P\sqrt{3})^2 + \frac{3L_0}{4AE}(Q\sqrt{3} + P) + \frac{3L_0 Q}{2AE} = 0. \quad . \quad . \quad . \quad (32)$$

Equation (32) is a quadratic equation for Q, giving

$$Q = P\sqrt{3} - \frac{4}{c_2 L_0^2}\left\{c_1 + \frac{3(2+\sqrt{3})}{AE}\right\} + \sqrt{\left[\frac{16}{c_2^2 L_0^4}\left\{c_1 + \frac{3(2+\sqrt{3})}{AE}\right\}^2 - \frac{48(2+\sqrt{3})}{c_2 AE L_0^2}P\right]}.$$

Example 11.—Repeat example 10 if the member DE was initially λ short and had to be forced to fit the frame.

Now that the characteristics of the structure are not linear we cannot consider the self-straining effect separately as we did in example 9. The entire solution must be repeated.

Expression (31) for S will still hold good, as the expressions for the forces in the members were found from consideration of equilibrium only; and on applying the second theorem of complementary energy in its form for self-strained structures we obtain equation (32) with λ instead of zero on the right-hand side. This slightly modified quadratic equation for Q has only a slightly modified solution, but note that the modification is not by linear addition of a term in λ:

$$Q = P\sqrt{3} - \frac{4}{c_2 L_0^2}\left\{c_1 + \frac{3(2+\sqrt{3})}{AE}\right\} + \sqrt{\left[\frac{16}{c_2^2 L_0^4}\left\{c_1 + \frac{3(2+\sqrt{3})}{AE}\right\}^2 - \frac{48(2+\sqrt{3})P}{c_2 AE L_0^2} + \frac{32\lambda}{c_2 L_0^3}\right]}.$$

Acknowledgment.—The author is indebted to Mr. A. C. Cassell, B.Sc. (Eng.) and other of his colleagues at the Imperial College of Science and Technology for several helpful criticisms and suggestions.

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[12] S. Timoshenko, *Theory of Plates and Shells*. McGraw-Hill Book Company, 1940.

* * *

BRIGHTNESS OF THE STARS

Instituted in 1951 to commemorate the important contributions to illuminating engineering made by the late A. P. Trotter and Sir Clifford C. Paterson, the third Trotter Paterson Memorial Lecture was delivered at the Royal Institution on March 9, under the auspices of the Illuminating Engineering Society. The lecturer was Sir Harold Spencer Jones, Sc.D., F.R.S., the Astronomer Royal, and his subject was "The Brightness of the Stars."

Sir Harold commenced his lecture by pointing out that brightness was not an intrinsic property of a star, saying that he proposed to deal with magnitude, or apparent brightness. Stars had been first graded into magnitudes by the Greek astronomer Hipparchus in 130 B.C. and the assignment of magnitudes had been continued by astronomers ever since. Magnitudes had been estimated by visual comparison in telescopes when that instrument had been invented and subsequently by photometric methods. More recently, photography and the photo-electric cell had been employed. Sir Harold explained fully the methods employed for measuring and comparing stellar magnitudes and for dealing with such disturbing factors as atmospheric absorption, colour differences, etc.

* * *

DISCOVERY OF HIDDEN ORES

Geochemical Prospecting

In general, the metal and mineral raw materials of industry have been won in the past from orebodies exposed or comparatively close to the earth's surface. The ever-increasing use of these raw materials, however, indicates that they will soon have to be obtained from greater depths. It is certain that vast mineral wealth awaits discovery beneath a concealing blanket of forest, soil, or barren rock, and has hitherto escaped detection by the established methods of exploration. The Research Report of the Royal School of Mines for 1950–53, gives details of the research work done by the Department of Mining Geology into geochemical techniques which will help in the discovery of some of the hidden minerals.

The methods of geochemical prospecting rely on the presence of traces of metal dispersed in the rocks, soils and vegetation surrounding an orebody. Near a hidden orebody there are anomalous concentrations of metals in the surface vegetation and the surface itself, and it is the detection of these "anomalies" that is the basis of geochemical prospecting.

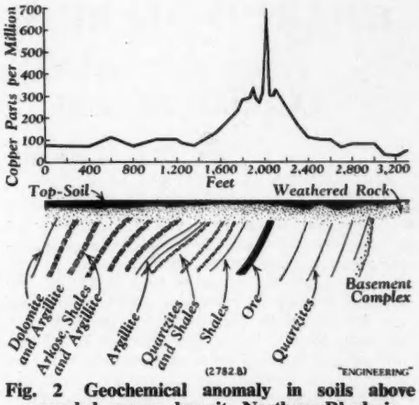

Fig. 2 Geochemical anomaly in soils above concealed copper deposit, Northern Rhodesia.

Anomalies in the natural distribution pattern of metals must be found by rapid methods of sample collection and analysis. The metal concentrations involved are often very minute, and a basic problem has been to find suitable techniques for analysing the samples. The ideal is to find quick routine tests which can be operated by semi-skilled men; fortunately, although high sensitivity is necessary, the difference between normal and anomalous concentrations is often three- to ten-fold so that only a moderate degree of accuracy is required. But to provide suitable field analytical methods is the problem that must be solved if low-cost geochemical prospecting is to develop. As an example of what field methods have been achieved, Fig. 1 shows a complete field laboratory for determining traces of copper and zinc in water; this particular test is capable of detecting 0·002 part per million of the metals in question and each determination takes only a few minutes to perform.

Geochemical prospecting techniques have been used in temperate regions for the detection of lead, zinc, copper, silver, tungsten, nickel, cobalt, uranium and several other elements. The Department of Mining Geology is concentrating its research on the use of the techniques in tropical countries, particularly the African Colonies. It has been found that the sampling of soil rather than vegetation gives the more reliable results, and in Nigeria systematic analysis has indicated strong metal anomalies over known lead-zinc veins. In the copper-cobalt field of Northern Rhodesia significant traces of copper have been readily detected in near-surface soils for several hundreds of feet on either side of a deeply weathered, mineralised shale horizon. A geochemical profile and plan are shown in Fig. 2.

In some cases the results of tests over known orebodies are not what would be expected. This is generally due to surface disturbance resulting from past mining activities, and interferes considerably with geochemical studies in Britain. Obviously, the investigations are more reliable when carried out where there has been little previous surface disturbance. Recent investigations in Southern Rhodesia (arsenic and antimony in soils, related to gold-bearing veins); in Sierra Leone (nickel in soils); and in Uganda (copper-cobalt, tin, tungsten, niobium and bismuth in soils and stream sediments), have been most encouraging.

It must be emphasised that geochemical prospecting is still in the experimental stage, although it has already produced many useful results. Each investigation has revealed limitations and the need for a clearer understanding of the agencies which control trace-metal dispersion. It is clear, however, that when fully developed and prudently applied the methods promise to play an important part in future mineral exploration, particularly in difficult tropical and glacial terrains.

Fig. 1 The field laboratory in use in Northern Rhodesia can detect 0·002 part per million of copper or zinc in water, each test taking only a few minutes.

GEARED MARINE TURBINE DRIVES

TORSIONAL VIBRATION CHARACTERISTICS EXAMINED BY DIRECT ELECTRICAL ANALOGY

By J. P. Duncan, M.E., A.M.I.MECH.E.*

The design of a multi-cylinder geared marine turbine propulsive unit is govered by a complex set of requirements ranging from thermodynamic considerations to engine-room space allocation. When all such requirements have been satisfied, the resulting system of turbines, shafts, gears and propeller must be examined for its torsional-vibration characteristics. Should there be a likelihood of gear hammer or unsafe amplitudes occurring within the working speed range, final modifications to the design may be necessary to obtain desired characteristics.

This article reviews means by which the essential charactristics of a given system may be rapidly assessed in advance of detailed calculation. A method of displaying the frequency-response curve by means of an electrical analogue of the mechanical system is described.

ELEMENTS OF A TYPICAL DYNAMIC SYSTEM

The diagram in Fig. 1 (*a*) shows the elements of a two-cylinder machine developing 7,300 brake horse-power at 100 r.p.m. as first presented for the examination of its torsional vibration characteristics. The reduction of this system to an equivalent one-speed system running at the speed of the slowest shaft may be effected by multiplying lumped elements by the appropriate factors shown below:—

Quantity	Symbol	Factor
Inertia	J or $I = \frac{J}{g}$	G^2
Stiffness	k	G^2
Torque	T	G
Angular displacement	θ	$\frac{1}{G}$

where G is the gear ratio of the element concerned with respect to the lowest speed shaft and g is the acceleration due to gravity.

Applying such ratios to the system of Fig. 1 (*a*), Fig. 1 (*c*) is obtained. Due to the comparatively large inertia at A and the comparatively large stiffness of shaft DC, it is possible to reduce the system to the simplified one-speed system shown in Fig. 1 (*c*). The natural torsional frequencies of branches EBA and EDC about E as node will be found to be identical with those of EL and EH respectively.

TORQUE RELATIONSHIPS

The propulsive, exciting and damping torques operating on the system are related. The torque developed by a propeller at various hull speeds is determined by the characteristics of the hull and propeller. For conventional installations, the relationship between propeller-torque and shaft-speed is controlled by the hull-propeller performance and is found to be approximately $Q = K\Omega^2$ where

Q = propulsive torque, lb.-ft. units,
Ω = angular speed, radians per sec., and
K = a constant.

Thus if the relation between torque and speed at normal or maximum rating is known, the corresponding value of torque at other speeds may be calculated making use of the above relationship.

At normal or maximum rating, the percentage of total power developed by each of the high-pressure (H.P.) and low-pressure (L.P.) turbines respectively will be determined by the design of the two machines. The power ratio at rated or maximum loading is a quantity arbitrarily decided by the turbine designer, but its value at part load conditions will be determined by the speed characteristics of the individual cylinders.

Denoting the percentage of total power developed by the H.P. cylinder as y,

$$\text{Total power} = P = Q\frac{\Omega}{550} \text{ S.H.P.}$$

$$\text{H.P. power} = \frac{yP}{100} \text{ S.H.P.}$$

$$\text{L.P. power} = \frac{(100-y)P}{100} \text{ S.H.P.}$$

Torsional vibrations in this equivalent system are usually excited by propeller torque variations. The propeller will develop under power a mean propulsive torque, Q, about which periodic variations will occur as the blades pass through a variable slipstream. The fundamental amplitude of these variations will depend on the characteristics of the slip-stream round the ship's stern and is usually expressed as a percentage of mean propulsive torque. Here this amplitude has been assumed to be $Q_x = x\,Q$. Wherever possible experimentally determined values of x, appropriate to the type of stern and propeller employed, should be used. In the example considered below, x has been given the value of 0·15.

The fundamental frequency of this periodic disturbing torque will be determined by the number of propeller blades. Denoting the number of blades as p, and the propeller-shaft angular speed as Ω, the angular frequency of the exciting torque will be $\omega = p\,\Omega$ rads. per second.

Damping torques arise from two major causes: (*a*) propeller damping, and (*b*) internal damping. It can be shown[1] that the damping torque applied by the propeller is $-b\dot{\theta}_f$ where

$\dot{\theta}_f$ = angular displacement of the propeller from datum,

b = damping coefficient $= \frac{4Q}{\Omega} = \frac{4K\omega}{p}$

Q = propulsive torque $= K\Omega^2$.

Internal damping though real and significant is sometimes ignored in analysis. It arises from energy losses within the turbines, bearings and

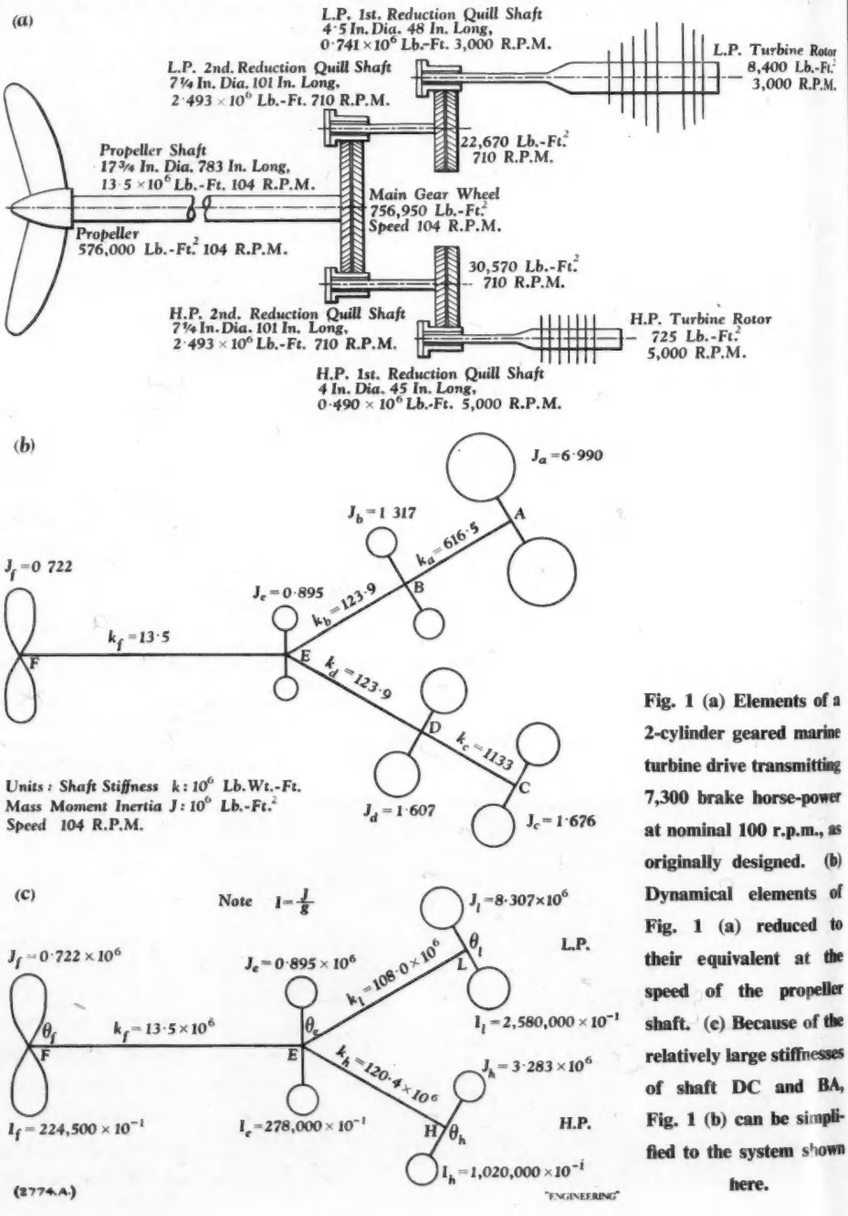

Fig. 1 (a) Elements of a 2-cylinder geared marine turbine drive transmitting 7,300 brake horse-power at nominal 100 r.p.m., as originally designed. (b) Dynamical elements of Fig. 1 (a) reduced to their equivalent at the speed of the propeller shaft. (c) Because of the relatively large stiffnesses of shaft DC and BA, Fig. 1 (b) can be simplified to the system shown here.

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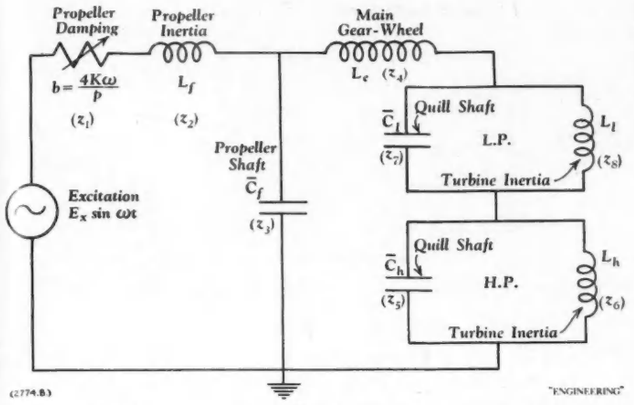

Fig. 2 Equivalent electrical circuit of reduced one-speed system shown in Fig. 1 (c).

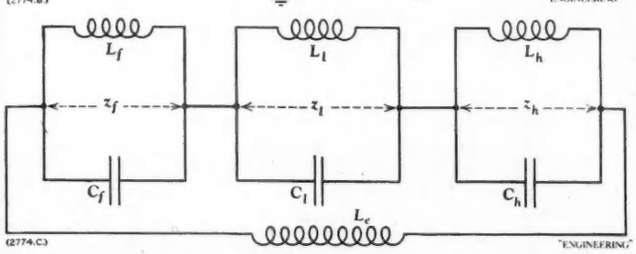

Fig. 3 The equivalent free circuit evolved from that in Fig. 2 by removing the damping elements and the excitation.

couplings and from shaft hysteresis. Energy losses from these several causes may be shown to be proportional to θ and $(\dot{\theta})^n$ where $n = 0$, 1 or 2. For convenience in practical calculations, however, the damping may be thought of as a rate of energy loss within the system expressed as a percentage of vibratory energy per cycle. Using a coefficient D for $\dot{\theta}$ to express the velocity-dependent damping torque, over any shaft of stiffness k:—

$$T = k\theta + D\dot{\theta}$$

for a torque in the shaft. It may then be shown[1] that if

$$\gamma = \frac{\text{energy dissipation per cycle}}{\text{total vibrational energy}} = \text{constant},$$

then

$$D\omega = \frac{\gamma k}{2\pi} = \epsilon k = \text{constant},$$

$$\epsilon = \frac{\gamma}{2\pi},$$

and

$$T = k(1 + j\epsilon)\theta, \quad \text{where} \quad j = \sqrt{-1}.$$

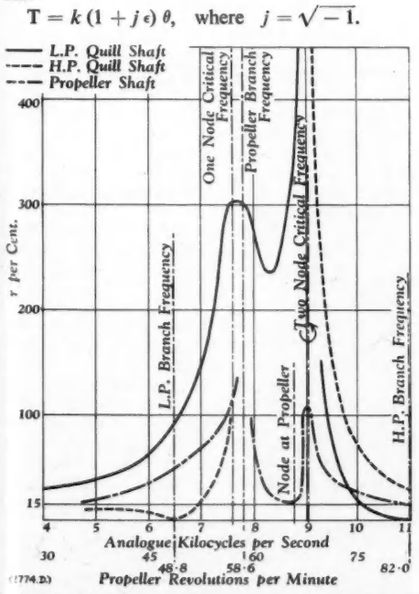

Fig. 4 Frequency-response curve for system of Fig. 1 (c) obtained by calculation using the Hölzer method.

If the rate of energy dissipation is assumed to be constant throughout the shafting system, internal damping may be allowed for by treating each shaft torque as a vector with a constant phase displacement of arc tanϵ or alternatively by regarding each shaft stiffness as a complex quantity, $k(1 + j\epsilon) = \bar{k}$. Even for 30 per cent. energy absorption per cycle, arc tanϵ is only $2\frac{3}{4}$ deg.

EQUIVALENT ONE-SPEED SYSTEM

By inspection of Fig. 1 (c) and from considerations given above to damping and excitation torque, the differential equations of the system are seen to be as follow :—

$$I_l \ddot{\theta}_l + \bar{k}_l(\theta_l - \theta_e) = 0$$

$$I_h \ddot{\theta}_h + \bar{k}_h(\theta_h - \theta_e) = 0$$

$$I_e \ddot{\theta}_e + \bar{k}_f(\theta_e - \theta_f) - \bar{k}_l(\theta_l - \theta_e) - \bar{k}_h(\theta_h - \theta_e) = 0$$

$$I_f \ddot{\theta}_f + b\dot{\theta}_f - \bar{k}_f(\theta_e - \theta_f) = Q_x \sin \omega t$$

where

$I_n = \frac{J_n}{g}$ $(n = l, h, e \text{ or } f)$,

g = acceleration due to gravity,

$\bar{k}_n$ = shaft stiffness $= k_n(1 + j\epsilon)$, $(n = l, k, e \text{ or } f)$,

$\epsilon = \frac{\gamma}{2\pi}$,

$\gamma = \frac{\text{energy dissipation in a shaft per cycle}}{\text{maximum energy of vibration}}$,

Q_x = excitation torque $= x\,Q = x\,K\,\Omega^2 = \frac{x\,K\,\omega^2}{p^2}$,

ω = angular frequency of vibration,

x = ratio of excitation to power torque,

p = number of propeller blades, and

b = propeller damping constant $= \frac{4\,K\,\omega}{p}$.

In dimensionless form, these equations are as follow. Writing $X_n = \frac{\theta_n}{\lambda}$ and $T = \psi t$, where λ is a dimensionless ratio and ψ a time-scale factor having the dimensions of angular frequency

$$\frac{d^2X_l}{dT^2} + \left[\frac{\bar{k}_l}{I_l \psi^2}\right](X_l - X_e) = 0$$

$$\frac{d^2X_h}{dT^2} + \left[\frac{\bar{k}_h}{I_h \psi^2}\right](X_h - X_e) = 0$$

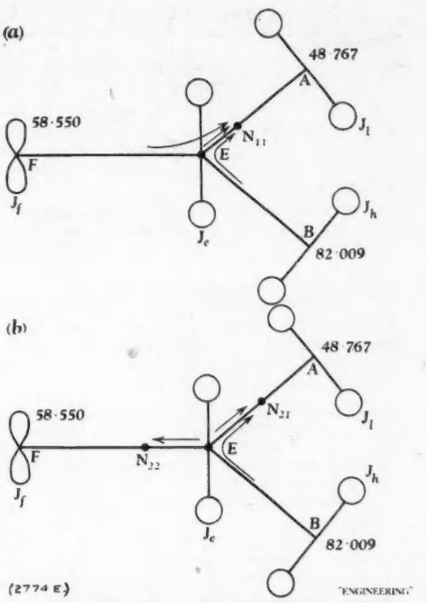

Fig. 5 Nodal patterns and critical speeds. (a) One-node mode: critical speed, 57·13 r.p.m. (b) Two-node mode: critical speed, 67·63 r.p.m.

$$\frac{d^2X_e}{dT^2} + \left[\frac{\bar{k}_f + \bar{k}_l + \bar{k}_h}{I_e \psi^2}\right]X_e - \left[\frac{\bar{k}_f}{I_f \psi^2}\right]X_f - \left[\frac{\bar{k}_l}{I_l \psi^2}\right]X_l - \left[\frac{\bar{k}_h}{I_h \psi^2}\right]X_h = 0$$

$$\frac{d^2X_f}{dT^2} + \left[\frac{b}{I_f \psi}\right]\frac{dX_f}{dT} + \left[\frac{\bar{k}_f}{I_f \psi^2}\right]X_f - \left[\frac{Q_x}{I_f \lambda \psi^2}\right]\sin\left[\frac{\omega}{\psi}\right]T = 0.$$

Making the substitutions

$\bar{k}_n = \frac{1}{C_n} = \frac{1}{\text{complex capacitance}}$,

$I_n = L_n$ = inductance,

$\theta_n = q_n$ = electric charge,

$b = R$ = variable resistance, and

$Q_x = E_x$ = variable voltage,

the above equations describe the behaviour of the electrical circuit of Fig. 2. Provided the dimensionless factors in brackets are identical for the mechanical system and electrical network, the behaviour of the mechanical system can be deduced from theoretical or experimental studies in the electrical network.

In the present case the ratio of exciting torque to the torque in any shaft at a given propeller-shaft speed, that is the dynamic magnifier, can be deduced from the ratio of corresponding voltages, calculated or measured from the analogue.

ANALOGUE SYSTEM BEHAVIOUR

Denoting the impedance of a circuit element by a complex number z with appropriate suffix, it will be noticed that the free undamped circuit may be represented as in Fig. 3, showing three tank circuits in series with an inductance L_e corresponding with the main gear wheel of the mechanical system. Excitation is in series with the elements of one of the tank circuits.

The impedance of the L.P. branch circuit in the free undamped system is

$$z_l = \frac{z_8 z_7}{z_8 + z_7} = \frac{(j\omega)}{C_l(\omega_l^2 - \omega^2)}, \text{ where } \omega_l^2 = \frac{1}{L_l C_l},$$

and that of the H.P. branch circuit is

$$z_h = \frac{z_8 z_6}{z_8 + z_6} = \frac{(j\omega)}{C_h(\omega_h^2 - \omega^2)}, \text{ where } \omega_h^2 = \frac{1}{L_h C_h}.$$

As these impedances tend to infinity at $\omega = \omega_l$

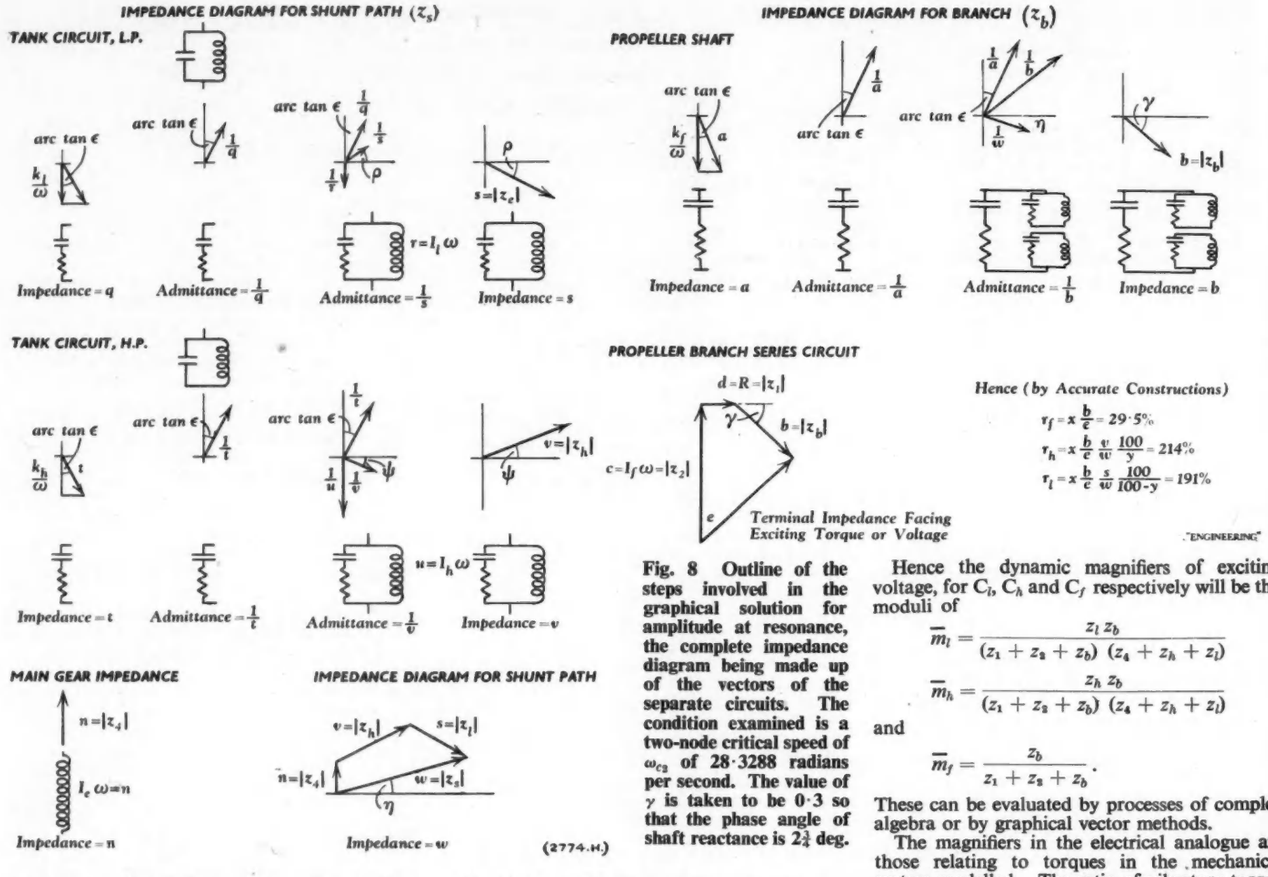

Fig. 8 Outline of the steps involved in the graphical solution for amplitude at resonance, the complete impedance diagram being made up of the vectors of the separate circuits. The condition examined is a two-node critical speed of ω_{c_2} of 28·3288 radians per second. The value of γ is taken to be 0·3 so that the phase angle of shaft reactance is $2\frac{3}{4}$ deg.

or $\omega = \omega_h$, the voltage across C_f at these frequencies will also appear across the tank circuit having the relevant branch-frequency ω_l or ω_h. The opposite tank circuit will not oscillate.

The impedance of the propeller branch circuit in the undamped system is

$$z_f = \frac{z_2 z_3}{z_2 + z_3} = \frac{(j\omega)}{C_f(\omega_f^2 - \omega^2)}, \text{ where } \omega_f^2 = \frac{1}{L_f C_f}.$$

Since this circuit is excited in series, however, the resonant voltage in C_f will excite the L.P. and H.P. branches to a certain degree and all branches will oscillate at $\omega = \omega_f$.

At resonance in the undamped system the sum of reactive voltages round the circuit must be zero, Hence

$$L_e(j\omega) + \frac{(j\omega)}{C_l(\omega_l^2 - \omega^2)} + \frac{(j\omega)}{C_h(\omega_h^2 - \omega^2)} + \frac{(j\omega)}{C_f(\omega_f^2 - \omega^2)} = 0. \quad . \quad . \quad . \quad (1)$$

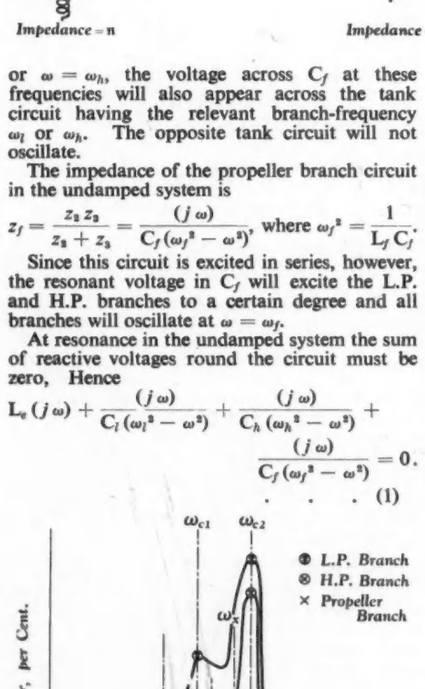

Fig. 6 Response curve constructed on the basis of critical and branch frequencies determined by use of the analogue.

For a three-cylinder machine a further term $\frac{(j\omega)}{C_i(\omega_i^2 - \omega^2)}$, representing the impedance of an intermediate-pressure (I.P.) branch, should be added to the left-hand side of the equation. The roots of this equation are the squares of the critical angular frequencies of the system. By expressing equation (1) as a cubic in ω^2 (two-cylinder machine) or a quartic in ω^2 (three-cylinder machine), all criticals may be obtained directly to any desired accuracy by the very simple Graeffe root-squaring method[2], elaborated in the Appendix on page 408. However it is obvious from equation (1) that two roots representing one and two-node modes will always lie between the branch frequencies ω_f, ω_l and ω_h, and that a third root representing a three-node mode will lie outside the interval between highest and lowest branch frequency. Hence the solution of this equation by trial numerical substitutions for ω^2 is a very simple matter, as ω_l, ω_h and ω_f can be evaluated immediately.

The impedance of the shunt path round C_f is

$$z_s = z_4 + z_h + z_l.$$

The impedance of the z_s and z_3 paths in parallel is

$$z_b = \frac{z_s z_3}{z_s + z_3}.$$

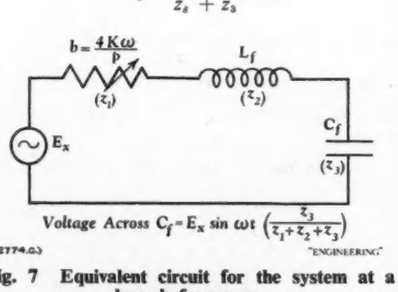

Fig. 7 Equivalent circuit for the system at a branch frequency.

Hence the dynamic magnifiers of exciting voltage, for C_l, C_h and C_f respectively will be the moduli of

$$\overline{m}_l = \frac{z_l z_b}{(z_1 + z_2 + z_b)(z_4 + z_h + z_l)}$$

$$\overline{m}_h = \frac{z_h z_b}{(z_1 + z_2 + z_b)(z_4 + z_h + z_l)}$$

and

$$\overline{m}_f = \frac{z_b}{z_1 + z_2 + z_b}.$$

These can be evaluated by processes of complex algebra or by graphical vector methods.

The magnifiers in the electrical analogue are those relating to torques in the mechanical system modelled. The ratio of vibratory torque to power torque in any shaft may be expressed in terms of x, y and $\overline{m}_n$ ($n = f, h, i$ and l) as

$$r_l = \overline{m}_l \frac{x(100)}{(100 - y)} \quad . \quad . \quad (2)$$

$$r_h = \overline{m}_h \frac{x(100)}{y} \quad . \quad . \quad . \quad (3)$$

$$r_f = \overline{m}_f x. \quad . \quad . \quad . \quad . \quad (4)$$

CHARACTERISTICS OF RESPONSE CURVES

Fig. 4, on page 405, is a frequency-response curve for the system of Fig. 1 (*c*) computed by the Hölzer method using a calculating machine. Some characteristic features of this curve are explained by the foregoing theory and could have been rapidly predicted, once the simplified equivalent one-speed system and its branch frequencies had been established. Methods of determining the essential features of this curve will now be outlined.

When the branch-frequencies of a system have been calculated it is possible to deduce qualitatively the disposition of nodes and approximate critical speeds of the system.

In calculating the branch frequencies, all branches are assumed to have their respective nodes at E in Fig. 5 (*a*). But all branches must actually vibrate at the same frequency. The nodes of each branch will move away from E at all frequencies of excitation other than a branch frequency in such a direction that the effective vibrating shaft-length increases or decreases. When this movement of the node among the branches results in a condition where all branches have a common frequency, a critical speed and resonance will have been reached.

Thus, in Fig. 5 (*a*), movement of the common node at E to N_1 will reduce the natural frequencies of propeller branch and H.P.-turbine branch and increase that of the L.P.-turbine branch until at some propeller speed all are the same. For the system of Fig. 1 (*c*), this speed turns out to be

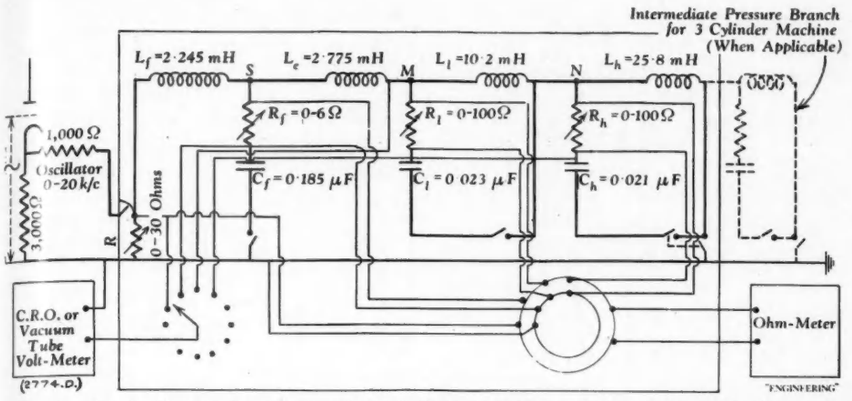

Fig. 9 Circuit diagram for the experimental direct electrical analogue of the mechanical system depicted in Fig. 1 (c). Scales with respect to mechanical system: frequency, × 2,000; capacity, × 2·5; inductance, × 10^{-7}.

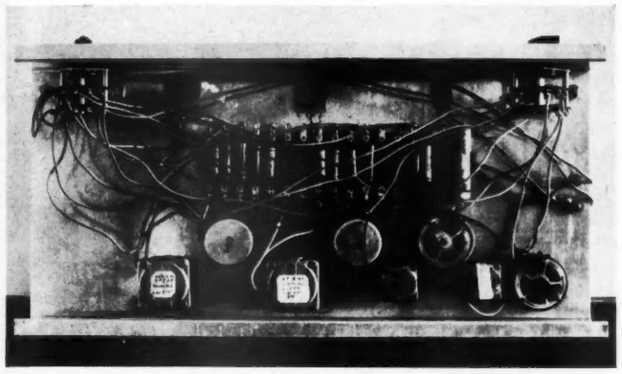

Fig. 10 The built-up circuit of Fig. 9, showing the physical arrangement of the components.

57·13 r.p.m., which is the single-node critical speed. The two-node mode results from a movement of nodes to positions N_{21} and N_{22} as depicted in Fig. 5 (*b*) and the corresponding critical speed is 67·63 r.p.m.

This process is a rough but fully effective method of interpreting the exact equation (1) given above. The disposition of the critical frequencies among the branch frequencies, shown in Fig. 5, can be determined by inspection.

SKETCHING THE RESPONSE CURVE

A structural basis for the response curve may next be drawn by erecting ordinates at critical and branch frequencies as in Fig. 6, opposite. At each ordinate the intersection of the response curves of all three shafts can be quickly determined with the aid of equations (2) to (4). At branch-frequencies ω_l and ω_h, the response of the H.P. and L.P. branches respectively will be zero for reasons previously given. At the same frequencies the response of the L.P. and H.P. branches respectively can be obtained by solving the simple circuit of Fig. 7, since the voltage across C_f (corresponding to the torque across k_f) is then the same as that across C_l and C_h respectively. Where the quill-shaft response curves determine the critical band width by intersection with $r = 100$ per cent., this computation represents a simple method of estimating resonant band width. The amplitude of all shafts at the critical frequencies may not be as important as an indication of band width where $r = 100$ per cent. but where maximum resonant amplitudes are required to assist further in sketching in the response curve, the graphical procedure outlined in Fig. 8, opposite, is quite rapid and adequately takes care of any distributed internal damping. The approximate response curves as shown in Fig. 6 may then be sketched in.

Other points may be found graphically as required. For instance, to determine the band width of resonance in the present example, a point for the H.P. shaft closer to ω_{c2} than ω_l would be more useful than the peak amplitude at ω_{c2}. The graphical method outlined could be used to find such a point. In cases where points are required *away* from resonance, elements of damping can advantageously be omitted with little loss of accuracy.

From the sketch of the response curve, the location and width of the band width of resonance at the onset of gear hammer where $r = 100$ per cent. can be quickly determined. In the example it is obvious that this band width may be reduced by bringing ω_l and ω_h closer together by changing quill-shaft stiffnesses or, where possible, inertia values. By making $\omega_l = \omega_h$ there will be no response in either branch at this frequency but a critical frequency will remain between ω_f and $\omega_l = \omega_h$. With a true nodal drive, $\omega_f = \omega_l = \omega_h$ and the amplitude at this common frequency would reduce to its lowest possible value, other conditions being fixed.

An index often used to measure torsional vibration characteristics is the value of x required to make $r = 100$ per cent. This can also be found from a calculation of peak amplitudes only.

A PHYSICAL ELECTRICAL ANALOGUE

While the calculation of the response curve for a given system by the Hölzer method is quite tedious, the method does lead to accurate solutions for a given set of data. However, the accuracy with which such data represents an actual system in service (particularly with regard to excitation and damping) is not likely to compare with the precision of the Hölzer tabulation. For this reason, the method of sketching in the response curve from data calculated at branch and critical frequencies is undoubtedly adequate for initial examination and modification of the system.

Where problems of this nature are of sufficiently frequent occurrence to justify the simple electrical components required, a physical electrical analogue with adjustable lumped-circuit elements permits the automatic plotting of a frequency-response curve on the screen of a cathode-ray oscilloscope. The effect upon response of an adjustment of a circuit element shows immediately on the screen. The need for any form of calculation may thus be eliminated.

To demonstrate the value and practicability of this approach, an experimental analogue of the mechanical system of Fig. 1 (*c*) was built and tested. Fig. 9 gives details of the circuit employed, Fig. 10 gives some idea of the physical appearance of the circuit. The resistors providing damping were variable and all other elements were fixed.

The frequency range chosen for the model was 1 to 14 kilocycles, corresponding to 7½ to 105 r.p.m. of the propeller shaft and representing a frequency ratio of 2,000. Inductances in henries were made 10^{-7} times the mechanical values of I and capacitances in farads, 2·5 times $\frac{1}{k}$. The values so obtained enabled the inductances to be wound on the newly developed "Ferroxcube" pot cores giving high quality factors. The capacity values are not so low that distributed capacities become a nuisance. The maximum impedance of any circuit element is of the order of $\frac{1}{10}$ of the input impedance of the cathode-ray oscillograph used to measure voltages. The general level of voltage was of the order of less than 1 volt at resonance. Low voltages are necessary when using metallic-cored inductances in parallel-resonant tank circuits due to the high circulating currents relative to line currents and the considerable drop in quality factors which result from hysteresis losses at high amplitudes.

The condensers were assumed to be perfect and resistance appropriate to each frequency was added in series to give the desired phase angle, arc tanϵ. The inherent loss-resistance of the associated inductance was deducted from the calculated value of resistance to be associated with each condenser. The correct propeller damping resistance at each frequency was adjusted manually.

Several improvised Q-meters were used to determine the inherent loss resistance of the inductances. The arrangement shown in Fig. 11, below, was finally adopted. The circuit diagram, Fig. 9, indicates switching arrangements for measuring component values and working voltages. The condenser voltages were measured as voltages above earth, the voltage across C_h being deduced from the numerical difference of points M and N. This is permissible since even with 30 per cent internal damping the phase angle of the reactive components near circuit resonance is very little different from $\pm\frac{\pi}{2}$.

COMPARISON OF ANALOGUE AND COMPUTED SOLUTIONS

Figs. 12 to 14, on page 408, set out the results which were obtained from the physical analogue as compared with the response curve calculated for zero internal damping, but with correct propeller damping. A few points for $\gamma = 0{\cdot}15$ and $\gamma = 0{\cdot}3$ computed graphically at critical frequencies are also shown.

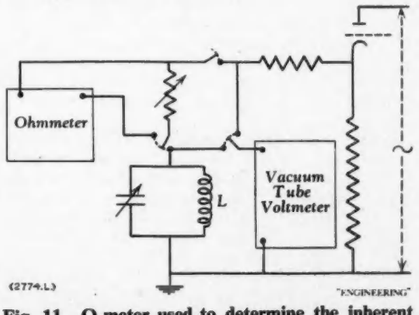

Fig. 11 Q-meter used to determine the inherent loss resistance of the inductances.

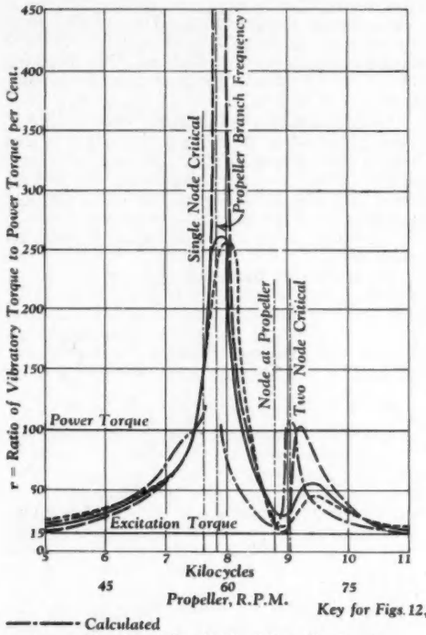

Fig. 12 The frequency-response curve for the propeller shaft.

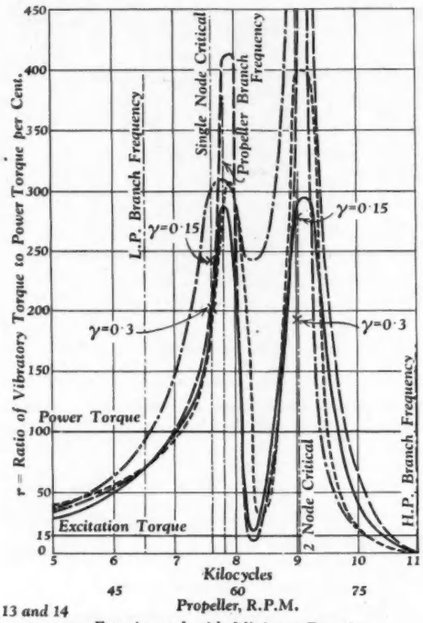

Fig. 13 The frequency-response curve for the low-pressure quill shaft.

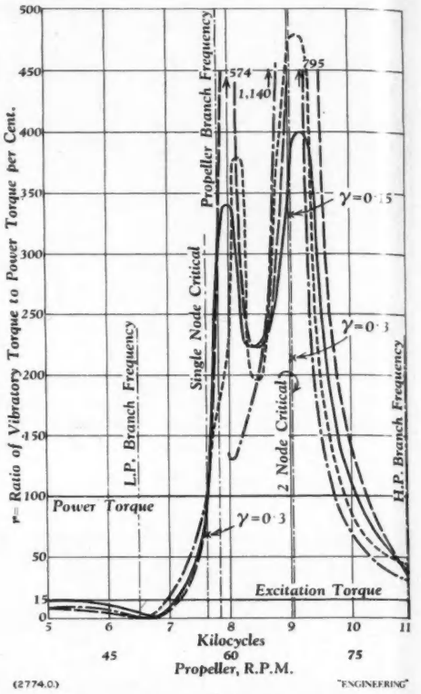

Fig. 14 The frequency-response curve for the high-pressure quill shaft.

Figs. 12, 13 and 14 The three sets of curves were obtained by setting the oscillator of the analogue, adjusting the damping resistances and comparing the exciter and the three condenser voltages.

The respective critical and branch frequencies correspond with the following values :

Frequency symbol Rads. per sec.	Mechanical system r.p.m. propeller	Electrical system k/cycles
ω_l	48·8	6·52
ω_{c1}	57·1	7·61
ω_f	58·6	7·82
ω_{c2}	67·6	9·0
ω_x	65·8 (app.)	8·77
ω_h	82·0	10·92

where ω_{c1}, ω_{c2} are critical frequencies, ω_x frequency at which all reactive torques or voltages are just balanced by exciting torque or voltage, and ω_h, ω_l, ω_f are branch frequencies.

AUTOMATIC PLOTTING OF THE FREQUENCY CURVE

The results given in Figs. 12, 13 and 14 were obtained by setting the oscillator at a desired frequency, manually adjusting the damping resistances throughout the circuit and comparing the exciting and the three condenser voltages. The method is a step-by-step one with the added advantage that the resonance peaks can be located very accurately, and peaks between steps in the tabular calculation were detected.

Since damping affects mainly the amplitude at resonance, and alters the response curve away from resonance very little, it would appear to be a sound experimental technique to find first the resonant frequencies by observation and set the damping resistances to the values appropriate to that frequency. Two independent response curves could then be obtained with damping set in turn to suit each resonant frequency.

If the frequency of the exciting voltage is made proportional to the travel of the cathode-ray oscilloscope spot in the XX-direction, the voltage in any condenser will be modulated during the scanning and the YY-amplitude will be proportional to m, the magnifier referred to earlier.

Fig. 15 reproduces a set of photographs of the response of each condenser of the model to a constant amplitude input signal. A variation of frequency with spot travel along XX was obtained by rotating a small plate condenser and allowing this variable capacity to swing the output frequency of a beat frequency oscillator. The spot was held at the left of the screen while the condenser disengaged after a scan from left to right. A mechanical contactor on the shaft of the rotating condenser was used for this.

No attempt was made to reduce the speed of scanning to a minimum with the result that transient electrical effects are undoubtedly present. This is apparent in the photographs taken with minimum damping. The employment of a reduced speed of sweep and a long persistence screen would avoid these distortions.

If one half of the input signal voltage is regarded as x per cent. of mean power torque, the top envelope will represent (with respect to the axis of symmetry) a curve of r against frequency for the propeller shaft, and to a different scale (depending on the division of power between H.P. and L.P.) r against frequency for the turbine branches.

Ideally, the above double envelopes should be rectified and filtered of high frequency to give a clear single-line trace of the same form as the curves for r against frequency obtained by calculation. However, the photographic records taken with different degrees of damping have not been rectified or filtered as they exhibit all the essential factors of interest. The photographs show clearly that internal damping affects the amplitudes at resonance and has a relatively much greater effect on the two-node resonance than on the single-node resonance. This demonstrates the serious errors introduced by ignoring internal damping in a Hölzer tabulation such as that used to produce Fig. 4. Here, the relatively small propeller amplitudes in the two-node mode result in small propeller velocities and thus small values for the term $-b\dot{\theta}_f$.

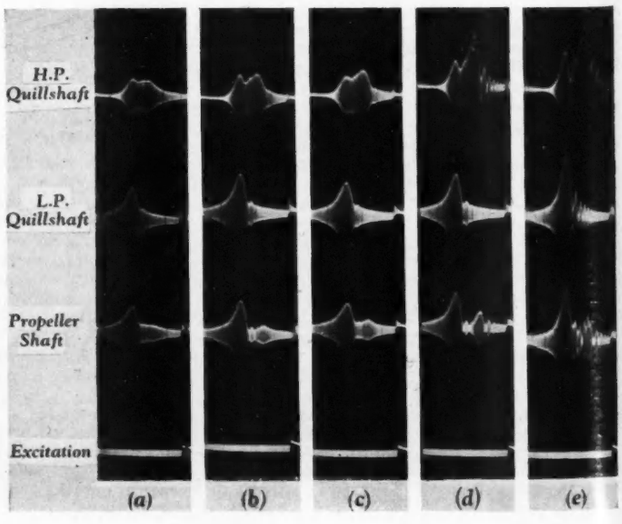

Fig. 15 Response envelopes obtained by automatic frequency scanning. (a) Heavy internal damping in H.P., L.P. and propeller branches. (b) Heavy internal damping in H.P. branch only. (c) Heavy internal damping in L.P. branch only. In (a), (b) and (c) the propeller damping was appropriate to a resonant frequency. (d) Heavy internal damping in propeller branch only, all damping at a minimum. (e) Minimum damping in all branches.

APPENDIX

Solution of Equation (1) by Graeffe Root Squaring Method

For the installation shown in Fig. 1 (*a*), page 404, equation (1) reduces to

$$\Omega^4 - 108{\cdot}6\,\Omega^3 + 1356\,\Omega^2 - 4380 = 0 \quad (5)$$

where

$$\Omega = \frac{\omega}{10}.$$

The Graeffe method first derives from equation (5) another equation whose roots are those of (5) raised to any selected large even power t. The relation between roots and coefficients or original and derived equations is as summarised below.

Original equation for solution : $x^3 + a_1x^2 + a_2x + a_3 = 0$

Roots of original equation : $r_1 > r_2 > r_3$

Derived equation by Graeffe method : $x^3+\alpha_1x^2 + \alpha_2x + \alpha_3 = 0$

Relation between r_i and α_i: $r_1 = \sqrt[t]{\alpha_1}$ $r_2 = \sqrt[t]{\frac{\alpha_2}{\alpha_1}}$ $r_3 = \sqrt[t]{\frac{\alpha_3}{\alpha_2}}$

t	1	α_1	α_2	α_3
1	1	a_1	a_2	a_3
2	1	$a_1^2 - 2a_2$	$a_2^2 - 2a_1a_3$	a_3^2
4	Find from $t = 2$ by repeating operation of finding $t = 2$ from $t = 1$			
	Etc.			

In the above table, x stands for Ω^2. Performing the operations shown in the table with the aid of a mechanical computer, the following figures were obtained:—

t	1	α_1	α_2	α_3
1	1	−108·6	+1,356	−4,380
	1	117·93 × 10^2 −27·12 × 10^2	183·87 × 10^4 −95·13 × 10^4	19·184 × 10^6
2	1	90·81 × 10^2	88·74 × 10^4	19·184 × 10^6
	1	82·464 × 10^6 −1·775 × 10^6	78·748 × 10^{10} −34·842 × 10^{10}	3·6803 × 10^{14}
4	1	80·689 × 10^6	43·906 × 10^{10}	3·6803 × 10^{14}
	1	65·107 × 10^{14} −0·009 × 10^{14}	19·277 × 10^{22} −5·939 × 10^{22}	13·545 × 10^{28}
8	1	65·098 × 10^{14}	13·338 × 10^{22}	13·545 × 10^{28}
	1	42·377 × 10^{30} −0·0000 × 10^{30}	177·90 × 10^{44} −17·64 × 10^{44}	183·467 × 10^{56}
16	1	42·377 × 10^{30}	160·26 × 10^{44}	183·467 × 10^{56}
	1	17·958 × 10^{62}	256·83 × 10^{80} −1·55 × 10^{80}	336·6 × 10^{114}
32	1	17·958 × 10^{62}	255·28 × 10^{80}	336·6 × 10^{114}
	1	3·2249 × 10^{126}	65,167·88 × 10^{160} −1·44 × 10^{160}	11·323 × 10^{232}
64	1	3·2249 × 10^{126}	6·5167 × 10^{184}	11·323 × 10^{232}

After 6 repetitions, roots Ω_1, Ω_2, Ω_3, corresponding to ω_1, ω_2, ω_3, were found:—

$$(\Omega_1{}^2) = \sqrt[64]{3{\cdot}2249 \times 10^{126}}$$

$$\Omega_1 = \sqrt[128]{3{\cdot}2249 \times 10^{126}}$$

$$\omega_1 = 10 \cdot \sqrt[128]{3{\cdot}2249 \times 10^{126}} = 97{\cdot}355 \text{ rads. per sec.}$$

$$\omega_2 = 10 \cdot \sqrt[128]{\frac{6{\cdot}5166 \times 10^{184}}{3{\cdot}2249 \times 10^{126}}} = 28{\cdot}543 \text{ rads. per sec.}$$

$$\omega_3 = 10 \cdot \sqrt[128]{\frac{11{\cdot}323 \times 10^{232}}{6{\cdot}5167 \times 10^{184}}} = 23{\cdot}815 \text{ rads. per sec.}$$

These give critical propeller shaft speeds comparing very favourably with those found independently by the Hölzer method using a calculating machine.

Critical Speeds

Mode	Graeffe method	Hölzer method
1 node	57·0 r.p.m.	57·1 r.p.m.
2 nodes	68·1 r.p.m.	67·6 r.p.m.
3 nodes	232·5 r.p.m.	234 r.p.m.

Acknowledgement.—This work was initiated at the Metropolitan-Vickers Electrical Company, Manchester, who kindly gave permission for its publication. Thanks are due to Professor H. H. Davis for the use of experimental facilities at the University of Adelaide and to Mr. B. Downs for drawing the author's attention to the Graeffe method.

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CONVERSION OF INCH AND METRIC SIZES ON ENGINEERING DRAWINGS*

By L. W. Nickols, B.SC.(ENG.), M.I.MECH.E., A.M.I.PROD.E.†

In this paper consideration is given to the factors involved in converting the British system of linear measurement on an engineering drawing to the metric, and conversely. These factors include: accuracy of measurement, the difference in size between the original and converted size, and the method of rounding the converted size. Finally, a logical and simple scheme for inter-conversion is described.

Since the end of the war the inter-conversion of inch and metric sizes on engineering drawings has assumed considerable importance in trade with foreign countries using the metric system. Some British firms have established manufacturing or assembly plants in these countries because of import limitations or for servicing purposes, and consequently it has been desirable to redimension inch-system engineering drawings in millimetres. On the other hand, foreign firms may find it necessary to redimension metric-system drawings in inches for use in this country. For defence purposes also, it may be desirable for British designs of weapons or aircraft engines to be manufactured in countries using the metric system, and conversely. The difficulty encountered in the conversion of these drawings arises when it is necessary to formulate a procedure for conversion, which ensures that components acceptable when inspected with respect to a drawing dimensioned in one set of units are not rejected when inspected with reference to the corresponding drawing dimensioned in the other set of units. Such dimensional interchangeability can, of course, be maintained by making the conversion to a very high degree of accuracy, that is, by calculating the converted size to a large number of decimal places. But there is little justification in the use of a number of decimal places not warranted by the available data, and too many decimal places in the converted size become an embarrassment in practical use.

In laying down a recommended procedure for conversion, using a recognised conversion factor as a basis, the problem is to obtain a suitable degree of precision in the converted value. Various factors have to be considered in deciding the optimum fineness of rounding the converted value. One of the most important is the inevitable inaccuracy of measurement always associated with any measured size. Because of this, a limit specified on an engineering drawing is not in practice a rigid line of demarcation, but is the mid-point of an ill-defined zone within which the true size falls when the measured size is the same as the specified limit. It is necessary also to decide how far the converted and rounded value may depart from the original size, bearing in mind the effect of any such departure on the manufacturing tolerance or the allowance between the mating features. Finally, the best method of rounding the converted limit has to be chosen: whether to round between or outside the original limits or to the nearest multiple of the fineness of rounding. All these factors are considered in the following paragraphs.

The conversion factor used is the simple relation 1 in. = 25·4 mm. This factor has legal sanction for use in trade in Great Britain and is the basis for the conversion of all linear measurements given in the Standards of the British Standards Institution. It is accurate to within two parts in a million, and this order of accuracy permits conversions to be made with errors which are negligible for ordinary engineering purposes.

The Effect of Inaccuracies of Measurement on the Interpretation of Sizes.—Any recommended procedure for the conversion of sizes from one system of units to another is necessarily dependent on the interpretation in practice of these sizes. If a theoretical size obtained by calculation is quoted to a certain number of decimal places it would be reasonable to assume, in the absence of other information such as a tolerance, that the actual size is required to conform with the theoretical size to within $\pm\frac{1}{2}$ of the unit in the last decimal place. This interpretation of a specified size cannot be applied to the sizes of features required to be universally interchangeable. The specified limits of size of such features are regarded in theory as being absolutely rigid without regard to the number of decimal places to which the limits are specified. For example, a limit may be stated on the drawing in the alternative forms 0·750 in. and 0·7500 in., but both these methods of statement mean that in theory the size of the limit is 0·7500 in. exactly.*

In practice, however, it is only possible to conform to the specified limits within the accuracy of the method of dimensional inspection adopted, whether by limit gauging or by direct measurement, the latter being generally the more accurate method. The theoretically rigid limit on the drawing becomes in practice an ill-defined zone, the mid-point of which is defined by the drawing limit. When the measured size is the same as the drawing limit, the true size may lie anywhere within a zone of width $2x$ disposed symmetrically about the drawing limit, where $\pm x$ is the accuracy of the method of measurement. It should be emphasised at this stage that the accuracy of direct measurement is not entirely dependent on the basic accuracy of the measuring instrument employed, but is affected to a considerable extent by such factors as the nominal size, the quality of surface finish

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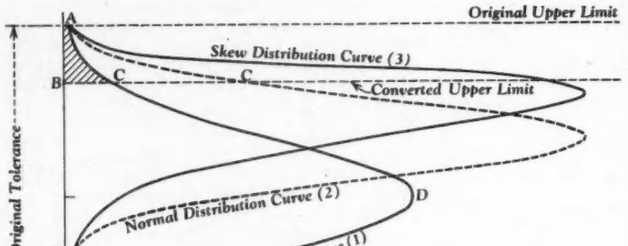
* B.S. 308 recommends, for values less than unity, a decimal point without a preceding 0. but to accord with ENGINEERING's practice the 0 is used.



Effect of precision of conversion on number of components rejected when inspected to converted limits. Area ABC represents 2½ per cent. of components; area ABC¹ represents 7 per cent. of components.

and the errors of geometric form of the feature being measured. It is reasonable to assume that the highest practicable accuracy of measurement is closely related to the tolerance on the feature, as the tolerance controls the surface finish and errors of geometric form, and is itself dependent on the nominal size of the feature.

The question then arises as to what is the attainable accuracy of measurement of an engineering component. Adams* has suggested that this accuracy of measurement is of the order of ±2 to ±4 per cent. of the component tolerance. This suggestion appears reasonable for components having tolerances of values down to 0·001 inch (0·025 mm.), at which value it corresponds to an accuracy of measurement of ±0·000 02 in. to ±0·000 04 in. (±0·5μ to ±1μ) providing that the surface finish and geometric form of the components are satisfactory. It is doubtful, however, whether a higher precision of measurement than about ±0·000 03 in. (±0·75μ) is attainable with present day measuring equipment of the types encountered in engineering inspection departments, and this precision of measurement will, of course, amount to a progressively increasing proportion of the component tolerance as the latter is reduced below 0·001 in. Thus for a component tolerance of 0·0003 in. (7·5μ), it is equivalent to ±10 per cent. of the component tolerance.

Summing up, in practice it is only possible to conform to specified limits of size within the accuracy of the method of inspection used, and this accuracy is unlikely to be better than about ±2 to ±4 per cent. of the feature tolerance if the latter is 0·001 in. or greater. For feature tolerances less than 0·001 in. the accuracy of measurement is unlikely to be better than ±0·000 03 in.

Effect of Differences in Size between Original and Converted Limits.—Before formulating a scheme for converting limits to a suitable degree of precision, it will be well to consider the effect of a difference in size between the original limit and the rounded converted limit. For this purpose, the original limit and the rounded converted limit are regarded as rigid, i.e., no account is taken of any practical variation in the limits due to the unavoidable inaccuracies of the method of dimensional inspection adopted.

It may be argued that a small fineness of rounding of the converted limit, so that its size agrees closely with the original limit, is not essential. The reason advanced in favour of this argument is that if the manufacturing process is under satisfactory control, then the size distribution curve of the component approximates to a normal (Gaussian) curve, and the converted limits can differ appreciably from the original limits without affecting to any noticeable extent the percentages of components accepted or rejected. This is illustrated in the above graph : the curve (1) representing the normal curve of components made so as to take full advantage of the tolerance AG. The shaded areas ABC and EFG indicate the additional number of components rejected when the converted limits are inside the original limits and differ from them by relatively large amounts AB and EG, which are in this case equal to one-sixth of the tolerance; the additional numbers of rejected components represented by each of the areas ABC and EFG are equivalent to only 2½ per cent. of the total number of components.

The above argument is not always correct for the following reasons. In the first place the tolerance is in most cases determined from functioning considerations, and should be as large as possible in order to render manufacture as easy as possible. A normal or size distribution curve applies to the particular manufacturing process used, and the " spread " of that curve is dependent on that process and may have no relation to the drawing tolerance, provided, of course, that it is smaller than the latter. It is quite permissible, although not desirable perhaps, for the manufacturing process to have the size distribution curve (2) which is not symmetrically placed within the tolerance zone AG. In this particular case, if the difference in size AB between the original and converted limits is equal to, say, one sixth of the component tolerance, then the percentage of components acceptable to the original limit and rejected to the converted limit, indicated by the area ABC¹, will be about 7 per cent., which is rather large. If the size distribution curve covering the range of size AH is a skew curve, as may occur in practice, then the percentage of components acceptable to the original limit A and rejected to the converted limit B may far exceed 7 per cent.; this is shown by curve (3).

REDUCED MANUFACTURING TOLERANCE

A further disadvantage arising from the particular example given, in which the converted limits fall well between the original limits, is that in the conversion the manufacturing tolerance is reduced appreciably. The larger the difference between the original and converted limits the greater will be the reduction in the tolerance. If the converted and rounded limit falls outside the original limits, and if the converted limit is the maximum metal limit of one of a pair of mating features, the allowance or minimum clearance between the features is reduced. If the difference between the original and converted limits is appreciable, this reduction in the allowance may be sufficiently large to affect adversely the assembly and functioning of the mating features.

Quite apart from the above considerations, any recommended procedure for conversion must be applicable to manufacture as a whole. It must not be applicable only to conditions of adequate manufacturing and statistical control. It must be suitable also for conditions, which it is hoped will be occasional but must not be neglected, in which the proportion of components made to sizes near the limit is large. From all aspects, therefore, it is very desirable for the converted limit to conform closely with the original limit.

Fineness and Direction of Rounding Converted Limits.—A small fineness of rounding the converted limit is desirable if the effects described above of the differences in size between the original and converted limits are to be reduced to a minimum. There are three alternative procedures which can be followed in rounding the converted limit. The first is to round to the nearest multiple of the fineness of rounding, irrespective of whether the converted and rounded limit falls between or outside the original limits. The second and third procedures respectively are to round the converted limits always between or always outside the original limits. If the fineness of rounding is denoted by y, then if the first procedure is adopted the rounded values will be within $\frac{1}{2}y$ of the original limits. If the second or third procedures are adopted, the rounded values may differ from the original limits by amounts up to y.

The first procedure is to be preferred, as, for a given fineness of rounding, the maximum difference between the original and converted limits is only one-half of that resulting from the use of the other two procedures. Another advantage of the first procedure is that, in the mean, the tolerance between the converted limits is the same as that between the original limits, and the allowance remains unchanged.

RECOMMENDED CONVERSION PROCEDURE

It hss been indicated earlier that in practice it is only possible to conform to specified limits of size to within the accuracy of the method of dimensional inspection used, and this accuracy is unlikely to be better than about ±2 to ±4 per cent, of the component tolerance for tolerances of 0·001 in. or greater. Also it is desirable that any difference between the original and converted limits be kept to a minimum, and that the converted limits be rounded in the most suitable manner.

The theoretical basis of the recommended procedure for converting limits is that if the converted limits are rounded to an accuracy better than that to which it is possible to control the original limits in practice, then effective dimensional interchangeability of components, referred respectively to the original and to the converted limits, is secured, and no inspection discrepancies or functional troubles are likely to arise. For work having tolerances of about 0·001 in. or greater this is accomplished by rounding the converted size to the nearest 5 per cent. of the component tolerance; the maximum difference in size between the original and converted limits will then be not more than 2½ per cent. For work having tolerances of less than 0·001 in., even if the surface finish and geometric form are good, the accuracy of measurement commonly attainable in the engineering industry is probably not better than ±0·000 05 in. and it is reasonable to assume that an accuracy of ± 0·000 03 in. is the best that could be realised in regular production. There is little point, therefore, in rounding the converted sizes to a fineness better than the nearest 0·000 05 in. or 0·001 mm. as appropriate, to result in a maximum error of conversion of 0·000 025 in. or 0·0005 mm., respectively.

In the proposed scheme the tolerances have been grouped in order to obtain a reasonably simplified procedure; to this extent it has been necessary to depart from the theoretical basis adopted, but the grouping has been so arranged that no additional loss of accuracy is introduced. The recommended fineness of rounding the converted limit for each group of tolerances is given in Tables I and II, and in these tables the maximum error in the conversion expressed as a percentage of the tolerance is given in column 4.

The case of a simple feature, such as a shaft or a hole, is dealt with first, and the recommended procedure is then applied to the more difficult

* Principles and Practice Governing Interchangeability and the Specification of Manufacturing Limits of Size, as influenced by Statistical Considerations. G. C. Adams. *Proc. I.Mech.E.*, vol. 167, page 2, (A) 1953.

case of a group of simple features which have to conform to a definite positional relationship with each other, for example, the bolt holes in a flange are simple features having sizes which must lie between specified limits, and, in addition, the position of each hole with relation to the others in the group is specified.

The recommended procedure has been made as straightforward as possible by giving it in the form of a number of rules, which are arranged in a logical sequence so that by following them no difficulty should arise in converting limits and tolerances from inch units into their metric equivalents and vice versa. Examples are also given showing the application in practice of the conversion rules.

Before giving the procedure in detail it is useful to recall the different ways in which limiting dimensions of interchangeable features are shown in engineering drawings. Examples of these different ways are given below; all have precisely the same meaning and show that the tolerance is 0·004 and the limits of size are 0·999 and 0·995, though the lower three are not recommended in B.S.308 : 1953, Engineering Drawing Practice.

$\begin{matrix}0{\cdot}999\\0{\cdot}995\end{matrix}$	$0{\cdot}999 - 0{\cdot}004$	$0{\cdot}995 + 0{\cdot}004$	$0{\cdot}997 \pm 0{\cdot}002$
$\begin{matrix}1{\cdot}000 - 0{\cdot}001\\1{\cdot}000 - 0{\cdot}005\end{matrix}$	$0{\cdot}999 \begin{matrix}+0\\-0{\cdot}004\end{matrix}$	$0{\cdot}995 \begin{matrix}+0{\cdot}004\\-0\end{matrix}$	

CASE 1—SIMPLE FEATURES

Rules for the Interconversion of Inch and Millimetre Limits

RULE 1.—*From the tolerance on the feature, by means of Table I or Table II, determine the fineness of rounding the converted value and accordingly the number of decimal places to be retained therein.*

Note.—When the tolerance is not given directly on the drawing it should be derived by subtracting the minimum limit of size from the maximum limit of size.

RULE 2.—*Convert the two limits of size in one system of units into the equivalent limits of size in the other system of units to two more decimal places than the number of decimal places to be retained in the final rounded value, using the conversion factor* 1 *in.* = 25·4 *mm.*

Note.—If the two limits of size are not directly stated on the drawing they should be derived. Thus, for a dimension stated as 0·999 − 0·003, the limits of size are 0·999 and 0·996.

RULE 3.—*Round the converted limits of size obtained by Rule* 2 *to the fineness determined from Rule* 1, *so that the rounded value is nearest the unrounded value.*

TABLE I.—*Conversion of Inch Limits of Size to Millimetre Limits of Size*

1	2	3	4
Tolerance on original inch limit		Fineness of rounding. Derived millimetre limits to be rounded to the nearest:	Maximum error in conversion expressed as percentage of cols. 1 and 2
From	Up to but not including		
0·0004 in.	0·0008 in.	0·001 mm.	Per cent. 5 to 2·5
0·0008	0·008		2·5 to 0·25
0·008	0·08	0·01	2·5 to 0·25
0·08	0·8	0·1	2·5 to 0·25

TABLE II.—*Conversion of Millimetre Limits of Size to Inch Limits of Size*

1	2	3	4
Tolerance on original millimetre limit		Fineness of rounding. Derived inch limits to be rounded to the nearest:	Maximum error in conversion expressed as percentage of cols. 1 and 2
From	Up to but not including		
0·01 mm.	0·05 mm.	0·000 05 in.	Per cent. 6·25 to 1·25
0·05	0·5	0·0001	2·5 to 0·25
0·5	5	0·001	2·5 to 0·25
	50	0·01	2·5 to 0·25

Notes.—(1) It is unimportant whether the rounded value falls inside or outside the unrounded converted limits. (2) If the unrounded value determined from Rule 2 falls exactly midway between the two adjacent rounded values, choose the even rounded value. For example, if the unrounded value is 12·012 50 and the fineness of rounding is 0·001, then the rounded value is 12·012. If the unrounded value is 12·013 50 then the rounded value is 12·014. The same rule applies if the fineness of rounding is 0·000 05. If, for example, the unrounded value is 1·091 525 0, then the rounded value is 1·091 50. If the unrounded value is 1·091 575 0, then the rounded value is 1·091 60.

Example 1.—Conversion into Millimetres of a toleranced Dimension 0·0703 + 0·0009 in.

The limits of size in inches are 0·0703 and 0·0712.

By Rule 1, the recommended fineness of rounding obtained from Column 3 of Table I for a tolerance of 0·0009 in. is 0·001 mm.

By Rule 2, the limits of size in millimetres to five decimal places, i.e., two decimal places beyond the three decimal places to which the fineness of rounding is given, are :—

$$0{\cdot}0703 \times 25{\cdot}4 = 1{\cdot}785\ 62 \text{ mm.}$$
$$0{\cdot}0712 \times 25{\cdot}4 = 1{\cdot}808\ 48 \text{ mm.}$$

By Rule 3, the millimetre limits of size are rounded to the nearest 0·001 mm., giving the values 1·786 mm. and 1·808 mm.

The millimetre limits of size calculated above may be stated on the drawing by either of the two forms of drawing statement recommended in B.S.308 : 1953 for unilaterally toleranced dimensions, namely :—

$$\begin{matrix}1{\cdot}786\\1{\cdot}808\end{matrix} \text{ or } 1{\cdot}786 + 0{\cdot}022 \text{ mm.}$$

Example 2.—Conversion into Inches of a Toleranced Dimension 25·000 + 0·030 mm.

The limits of size in millimetres are 25·000 and 25·030.

By Rule 1, the recommended fineness of rounding obtained from Column 3 of Table II for a tolerance of 0·030 mm. is 0·000 05 in.

By Rule 2, the limits of size in inches to seven decimal places, i.e., two decimal places beyond the five decimal places to which the fineness of rounding is given, are :—

$$25{\cdot}000 \div 25{\cdot}4 = 0{\cdot}984\ 252\ 0 \text{ in.}$$
$$25{\cdot}030 \div 25{\cdot}4 = 0{\cdot}985\ 433\ 1 \text{ in.}$$

By Rule 3, the inch limits of size are rounded to the nearest 0·000 05 in., giving the values 0·984 25 in. and 0·985 45 in.

The inch limits of size calculated above may be stated on the drawing in either of the following ways :

$$\begin{matrix}0{\cdot}984\ 25\\0{\cdot}985\ 45\end{matrix} \text{ or } 0{\cdot}984\ 25 + 0{\cdot}0012 \text{ in.}$$

Example 3.—Conversion into Inches of a Toleranced Dimension 57·000 + 0·050 mm.

The limits of size in millimetres are 57·000 and 57·050.

By Rule 1, the recommended fineness of rounding obtained from Column 3 of Table II for a tolerance of 0·050 mm. is 0·0001 in.

By Rule 2, the limits of size in inches to six decimal places, i.e., two decimal places beyond the four decimal places to which the fineness of rounding is given, are :

$$57{\cdot}000 \div 25{\cdot}4 = 2{\cdot}244\ 094 \text{ in.}$$
$$57{\cdot}050 \div 25{\cdot}4 = 2{\cdot}246\ 063 \text{ in.}$$

By Rule 3, the inch limits of size are rounded to the nearest 0·0001 in., giving the values 2·2441 in. and 2·2461 in.

The inch limits of size calculated above may be stated on the drawing in either of the following ways :—

$$\begin{matrix}2{\cdot}2441\\2{\cdot}2461\end{matrix} \text{ or } 2{\cdot}2441 + 0{\cdot}0020 \text{ in.}$$

CASE 2—GROUPS OF SIMPLE POSITIONAL FEATURES

Each group consists of a number of simple features, such as holes or pins, the sizes of which are toleranced in the normal way. These sizes are converted as described in Case 1. In addition, the relative positions of the simple features with respect to each other are toleranced. This may be done in either of two ways: by tolerancing the centre distances defining the true positions of the features, or by applying a " geometrical " positional tolerance to the true positions of the features. A " geometrical " tolerance is defined as " the maximum permissible overall variation of form or position about that shown on the drawing." In other words, it is the width or diameter of a tolerance zone within which the surface, or the middle plane or axis of the feature, is to lie.*

(*a*) Positional Features having Toleranced Centre-distances.

The toleranced centre distance is converted in the same way as the limits of size of a feature, using Rules 1, 2 and 3, and Tables I or II.

(*b*) Positional Features having Geometrical Positional Tolerances.

RULE 4.—*From the geometrical tolerance on the position of the feature, by means of Tables I or II, determine the fineness of rounding the converted positional dimensions and accordingly the number of decimal places to be retained therein.*

RULE 5.—*Convert the geometrical tolerances and the constructional dimensions defining the true positions of the features to two more decimal places than the number of decimal places to be retained in the final rounded value, using the conversion factor* 1 *in.* = 25·4 *mm.*

RULE 6.—*Round the converted geometrical tolerances and constructional dimensions obtained by Rule* 5 *to the fineness determined from Rule* 4, *so that the rounded value is nearest the unrounded value. See notes* (1) *and* (2) *to Rule* 3.

Example.—1·508 IN. (TP)
POSN TOL 0·005 IN. DIA

The above method of dimensioning, recommended in B.S.308 : 1953, means that the true position of a certain feature is located by a dimension 1·508 in. and the centre line of the feature is allowed to depart from that true position providing it falls within a 0·005-in. diameter circle.

By Rule 4, the recommended fineness of rounding obtained from Column 3 of Table I for a tolerance of 0·005 in. is 0·001 mm.

By Rule 5, the converted sizes in millimetres to five decimal places of the 1·508-in. dimension and the 0·005-in. tolerance, i.e., two decimal places beyond the three decimal places to which the fineness of rounding is given, are :

$$1{\cdot}508 \times 25{\cdot}4 = 38{\cdot}303\ 20 \text{ mm.}$$
$$0{\cdot}005 \times 25{\cdot}4 = 0{\cdot}127\ 00 \text{ mm.}$$

By Rule 6, the converted sizes are rounded to the nearest 0·001 mm., giving the values 38·303 mm. for the 1·508-in. dimension and 0·127 mm. for the 0·005-in. geometrical tolerance.

UNTOLERANCED GENERAL DIMENSIONS

These dimensions are usually unimportant and it is only necessary to round the converted values with discretion.

The recommended conversion scheme has been formulated in conjunction with the late Mr. J. E. Sears, C.B.E., M.A., M.I.Mech.E., and it was the intention that he should have been a joint author of this paper. The work described above was carried out as part of the Research Programme of the National Physical Laboratory, and this paper is published by permission of the Director of the Laboratory.

* B.S. 308 : 1953, " Engineering Drawing Practice."

INCREASED DRILLING EFFICIENCY

"Chipbreaking" Rib

By developing a drill which breaks metallic swarf into small chips, Firth Brown Tools, Limited, Carlisle-street East, Sheffield, 4, have produced a tool which promises to increase drilling efficiency considerably. With the Speedicut "Chipbreaker" drill, British patent No. 699716, the chip is severed from the work-piece along the full length of the cutting edges and slides down the face of the flute towards the chipbreaker rib. This rib is designed to impart a tight curling action to the chip, and with the cutting edges inclined at an angle to the chipbreaker rib a shearing action is also imposed. The rib and the controlled breaking of the chips can be seen in Fig. 2. The standard type drill gives chips which are mainly continuous and which can wrap dangerously round the flutes, as shown in Fig. 1.

INCREASED LIFE BETWEEN REGRINDS

The precision milled rib extends along the full length of the flutes, giving the chipbreaking action throughout the life of the drill. The addition of the chipbreaker rib gives increased strength of section without detracting from the normal amount of flute space; the drill thus becomes more rigid in operation, and this rigidity has shown a marked increase in the number of holes per regrind obtained.

It is not claimed that chipbreaking can be given on all materials and feed rates. Drilling at fine feeds per revolution on low tensile materials produces thin chips of high ductility which are passed along the flutes as a straight chip. When correctly point ground, ensuring equal length cutting edges and constant clearances, effective chip breaking has been achieved using 1 in. diameter Chipbreaker drills drilling low tensile mild steel at feeds per revolution of 0·004 in.

These new drills give faster drilling times due to the non-interference of the swarf when broken into small chips, and in deep hole horizontal drilling the number of withdrawals is greatly reduced; the small chips also permit the coolant to flow more freely to the point of the drill. Chipbreaker drills are made in sizes from $\frac{1}{4}$ in. to $1\frac{1}{4}$ in., Morse taper shanks Nos. 2 and 3. The makers state that further additions will be made to the range within the next few months.

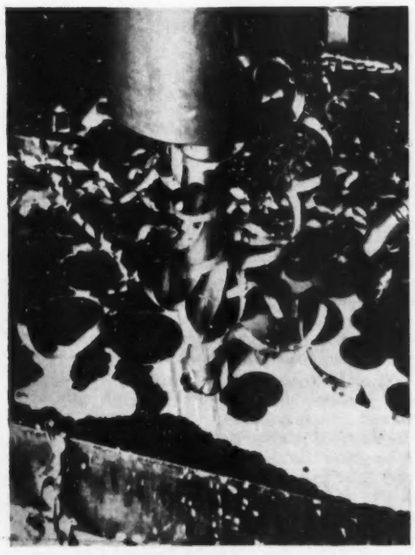


Fig. 1 With a standard drill the chips are mainly continuous and can wrap dangerously round the flutes.

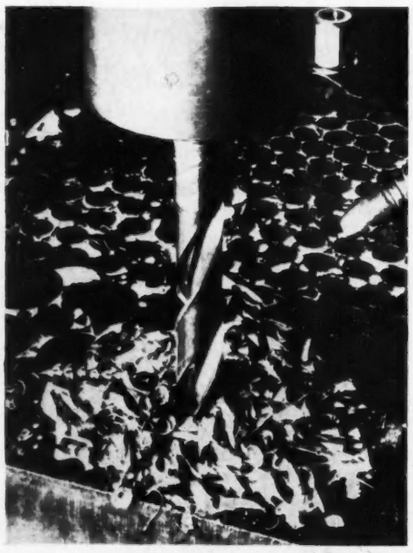


Fig. 2 The "Chipbreaker" drill produces chips which do not obstruct the drilling or the flow of coolant, and can be easily cleared away.

The handling and transporting of heavy billets can be performed by one man with the aid of the Head Wrightson Brosius "Manipulator," which is designed to guide the movements of a billet during forging, accurately and with ease.

MANIPULATING HEAVY BILLETS

Mechanical Handling Machine for Forging Operations

A mobile unit designed to transport metal billets from furnace to press or hammer, and to manipulate them throughout the entire forging operation, has recently been demonstrated at the Middlesbrough works of its makers, the Head Wrightson Machine Company, Limited, a subsidiary of Head, Wrightson and Company, Limited, Teesdale Iron Works, Thornaby-on-Tees, Yorkshire. Shown in the accompanying illustration and known as the Head Wrightson Brosius "Manipulator," this machine is also used to charge billets into the furnace and has a load-carrying capacity of 2,000 lb. It is built by the British company under licence arrangement with Salem-Brosius Inc., 248 Fourth-avenue, Pittsburgh 22, Pennsylvania, U.S.A., and enables one man to perform with comparative ease an operation which had hitherto required the services of several men, working in extremely hot and arduous conditions, together with an overhead crane.

Billets are gripped in jaws actuated by a hydraulic cylinder, and the capacity rating of 2,000 lb. is based on the assumption that the centre of gravity of the load is no more than 10 ft. from the centre line of the machine's front wheels. The jaws are designed to accommodate pieces of large cross-sectional area, and they can deal with material from 6-in. square to 24-in. square; other kinds of jaw suitable for use in particular cases can, however, be fitted when necessary.

WIDE RANGE OF JAW MOVEMENT

The gripping head is capable of a wide range of movement so that a skilled operator can manipulate the billet under the forging press with the same degree of control as was formerly achieved by hand. The work can be rotated continuously or intermittently in either direction by means of a hydraulic motor, through a heliocentric-gear reducer, and longitudinal motion is obtained by moving the complete machine with the aid of the traction drive. To position the forging on the anvil, and to allow for various anvil and furnace-hearth heights, the peel can be lifted vertically, tilted downwards and moved laterally; the downward tilt also enables billets to be picked from the ground.

An interesting feature of the manipulator is its capacity for lateral movement, which allows the work to be positioned on the anvil or in swages without moving the machine. The model demonstrated was capable of a lateral translation of 6 in. on either side of the longitudinal centre line, but versions with 12 in. of movement either side can be made. The front of the machine is supported by heavy coil springs which serve to absorb the shock of the forging blow.

Apart from traction, all motions of the equipment are hydraulically operated, the steering, litting, tilting, gripping and lateral shifting motions being effected by means of double-acting cylinders, and the rotation of the tongs head with the aid of a hydraulic motor. The hydraulic power for all these movements is supplied by a Hele-Shaw variable-volume pump driven by a 10-h.p. direct-current motor.

The manipulator is capable of a floor speed of 250 ft. per minute and is driven by an electric motor through gearing to a single driving and steering wheel at the rear of the machine. An electro-magnetic brake is attached to the motor and is automatically applied when the motor is stopped; by braking the traction drive at the source of the motive power greater sensitivity of control is obtained.

POWER SUPPLIED THROUGH FLEXIBLE ELECTRIC CABLE

The power for the separate drive units is obtained from the plant supply by means of a flexible cable and take-up reel, which leads to a slip-ring assembly mounted on a mast at the

rear of the machine. The manipulator operates on a 220-volt direct-current supply, but similar units deriving their power from self-contained Diesel engines are now also being built.

The controls are grouped conveniently around the operator, and both electrical and hydraulic controls are fitted with safety cut-out mechanisms. To give sensitive control of billet movement, operating speeds are comparatively slow; the tongs head, for example rotates at 10 r.p.m. The time required to lift the head with jaws loaded is 13 seconds, and the jaws can be opened or closed in 11 seconds.

The lowest and highest horizontal peel heights are respectively 2 ft. 1⅜ in. and 4 ft. 5 in. The machine, which is 17 ft. 11 in. long and 9 ft. 3 in. wide, is approximately 10 tons in gross weight, and is capable of turning in a circle of 12 ft. 9 in. radius. Although the capacity of the model demonstrated was only 2,000 lb., similar machines with capacities up to 20,000 lb. are built. Smaller machines of 500-lb. and 1,500-lb. capacity designed for the same purpose and also made by Head, Wrightson and Company, were described in ENGINEERING last year (vol. 177, page 829, 1954).

PHOTO-EPISCOPE FOR WORKSHOP USE

MAGNIFICATION UP TO 40 DIAMETERS

The accompanying illustrations show a convenient form of episcope for viewing or photographing objects at moderate magnifications. Although intended mainly for the examination of relatively small engineering parts, such as jet-turbine blades, and the inspection of watches and other small mechanisms, it can be used for many other purposes, including even surgical dissection. Normally, the object to be examined is placed on a circular plain work-table with vertical adjustment visible in Fig. 2 at the front of the instrument near the bench level, and the enlarged image appears on a translscent glass screen,7 in. square, at eye level, the image being sufficiently bright to be easily visible in a normally lighted room or workshop. The work-table can, however, be removed, leaving ample space for handling comparatively large objects. For photographing flaws, cracks, etc., the viewing screen can be removed and a panel with an extra screen and darkslide substituted for it. The overall dimensions of the episcope are: length 30 in., width 14 in., and height 26 in.

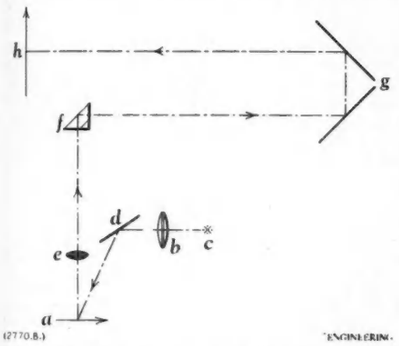


Fig. 1 Optical system of photo-episcope.

Fig. 1 is a diagram showing the optical system, in which *a* is the work-table, *b* a condensing lens, *c* the light source and *d* a mirror; *e* is a projection lens, *f* a roof prism, *g* are mirrors, and *h* is the viewing screen. The illuminating systems *c*, *b* and *d* are in duplicate. Alternative projection lens systems, which can be interchanged in a few moments, give undistorted images, free from colour fringing, at magnifications of 5, 17, or 40 diameters. There is also an additional large magnifier, with coated surfaces to reduce reflections, for magnifying the screen image about 1·5 times. It should be noted that the screen image is "correct"; that is to say it is neither reversed nor inverted. This is a convenient feature, as any movement of the object on the work-table occurs in the same direction on the screen. The fields of view for the three magnifications previously mentioned are, 1·4 in., 0·41 in., and 0·17 in. square, respectively. In the illuminating system, filters are provided which remove about 95 per cent. of the heat produced by the light source, so that there is no risk of damage to delicate objects on the work-table. Moreover, the convergence of the light can be adjusted to suit the magnification in use in order to secure an image of the maximum brightness when dark objects are being examined.

It should be made clear that the instrument is not intended for use with high magnifications for which satisfactory means are already available, but for continuous use in general bench inspections with the minimum of eye fatigue such as is often experienced with, say, binocular microscopes. Examples of the photographic work of the photo-episcope are reproduced in Figs. 3 and 4, but it should be pointed out that some of the definition is unavoidably lost in reproduction. The instrument is made by Mr. C. F. Smith, F.R.P.S., 1 Wood End Close, Farnham Common, Buckinghamshire.

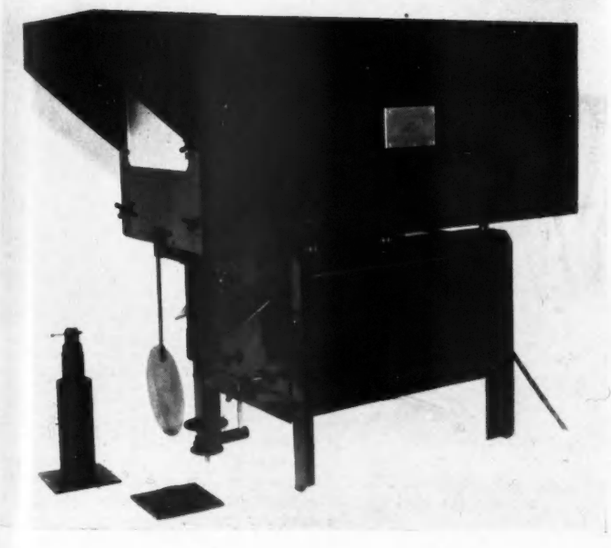


Fig. 2 Photo-episcope arranged for visual work. The object to be examined is placed on the circular table in front of the episcope. Magnifications of 5, 17 or 40 diameters can be obtained on the screen.

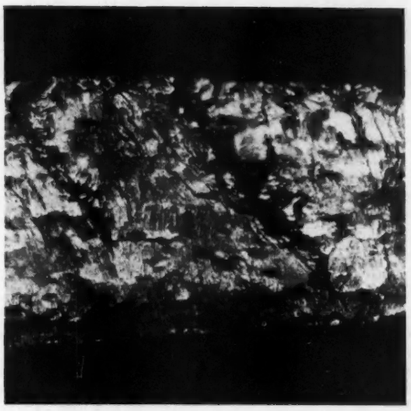


Fig. 3 Fracture of turbine blade in aluminium alloy × 15.

Fig. 4 Machining on side of ground gear-tooth × 15.

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EDUCATION OF THE CHEMICAL ENGINEER

The conference on "The Functions and Education of the Chemical Engineer in Europe," which took place in London from Monday, March 21, to Wednesday, March 23, and of which we gave an account on page 360 of our last issue, may now be described as a highly successful gathering. As was rightly said by Sir Harold Hartley in summing up the proceedings, both the authors of the papers and the speakers in the discussions made it abundantly clear that chemical engineering must be regarded as a primary technology. A stage of rapid evolution had in fact been reached, and it was therefore necessary to expand existing educational facilities.

More research, Sir Harold thought, was needed and this meant more financial support. The Research Institute for Process Technology at Aachen, which was jointly supported by industry, technical societies and the government, was an example that might be followed in this country. It was important to choose the right priorities in fields where the need was greatest. Here was a chance for closer European co-operation, as this would lead to an economy of effort and cost as well as an avoidance of over-lapping.

EQUIPMENT FOR THE FACTORY

WIDE RANGE OF ITEMS AT EARLS COURT EXHIBITION

The third Factory Equipment Exhibition is being held at Earls Court, London, from March 28 to April 2. As this year's show is nearly seven times the size of the first (1953) exhibition, this also can be counted among the successful ones. While the exhibition is open, three bodies are holding conferences. The British Productivity Council have had two sessions dealing with work study, illustrated by films and slides, on March 28 and 30. A series of talks, entitled " Fuel Efficiency Pays " was arranged for March 29 by the National Industrial Fuel Efficiency Service (see also page 320, *ante*); and the Institution of Works Managers are holding a conference with the theme " Maintaining prosperity by efficiency of management " during the last three days.

A large section of the exhibition is devoted to the protection and welfare of the employee. There are daily mannequin parades demonstrating protective clothing, now such an essential item in many factories, and displays of soaps and barrier creams for skin protection. Such items as paper handkerchiefs, paper soap leaves and hot-air hand driers are also being shown. Vacuum cleaners and ventilation plant are other aids to cleanliness and well-being that are on display.

On the more strictly engineering side, labour saving devices are well to the fore. No less than ten firms are showing fork-lift trucks of various sizes and for widely different purposes, and nine are showing conveyors. There are in addition, several exhibits of hand and power-operated trollies and other hydraulic lifting equipment. Another large section of the exhibition is devoted to office equipment, shelving, business machines and the like. In the following article a few of the exhibits are described

The exhibition was officially opened on March 28 by Sir Miles Thomas, the chairman of B.O.A.C. In his speech, Sir Miles recalled that he had opened the first exhibition in 1953, and had then wished them well. The enormous increase in size, and he understood that it would be increased again next year, showed how popular it had been. It was an exhibition with a particular significance in view of the present enormous factory expansion in this country. Equipment of all types was being shown which would reduce production costs and enable firms to utilise their potential capacity to the full. Much had been written in the past about the dignity of labour and this could be enhanced by the removal of drudgery and the economic use of energy. In conclusion, Sir Miles drew attention to the growth of industrial welfare both in the factory and out of it, and the introduction of such things as sports grounds, canteens and ambulance rooms.

The central feature of the exhibition is a model sports ground, one twenty-fifth full size, as might be designed for the ideal works. The model was made by Tubewrights, Limited, 25 Buckingham-gate, London, S.W.1, acting in conjunction with the National Playing Fields Association and at the invitation of the exhibition organisers. In one half there is a sports arena, in which is laid a football pitch encircled by cinder tracks for running and cycle-racing. Other activities catered for are bowls, cricket, tennis and swimming. The model is illuminated by a full-size floodlighting tower, 46 ft. high, placed in the centre, and is enclosed by examples of the firm's fencing, crush barriers and gates. On their stand, Tubewrights are showing various types of pallets, vehicle frames and the like, together with models and photographs of tubular bridges, gantries and buildings.

MARKING CRATES AND PARCELS

It is essential that packages for shipment should be clearly marked, and a system for doing this is being shown by Paul Plura and Company, Limited, 35 Kensington Park-road, London, W.11. Known as the Kabey system, the stamps are made of resilient rubber and are assembled in an aluminium-alloy holder, either curved or straight as required. The stamps are mounted on dovetailed blocks for easy assembly and have a metal letter on the top to aid composition. Examples are shown in Fig. 1. Type sizes range from 1 in. to 8 in. high. Inks suitable for impressing on wood, metal, canvas, etc., are available. The firm are also showing branding stamps which can be heated electrically, by petrol, or by an open fire.

PROGRESS CONTROL INDICATOR

The Archimedes-Diehl-Machine Company, Limited, Chandos House, Buckingham-gate, London, S.W.1, are showing the " Vidento " visual control system which they have introduced into this country during the last few months. The indicator panels as shown in Fig. 2, have 62 numbered columns with identity labels at the foot. These columns are filled to the required height by small steel balls, of which 16,000 are stored in a reservoir at the top. Pressing one of the buttons in the top row allows a single ball to fall into the corresponding column; pressing one of the lower buttons allows one to fall into a tray in the base of the panel. In this way the heights of the columns can be adjusted. Each column can hold 220 balls. If it is required to fill or empty a column quickly, a master button can be used which overrides the " single " mechanism. In order to prevent unauthorised use, the whole mechanism can be locked by a removable key. The front of the board is covered with Plexiglass, rendering the panel practically dustproof and giving a convenient surface for crayon-written notes. Provision is also made for stretching cords across the board to act as day or hour lines for use in particular when the panel is being used for machine loading. In this way a check can be kept on the allocation to each machine. The entire indicator measures 2 ft. 4 in. wide by 2 ft. 7 in. high by 5½ in. deep.

Fig. 1 Letters and numbers to be assembled into holders for marking cases or bales.

HANDLING WITHOUT PALLETS

The increasing use of fork-trucks for materials handling has led to a wide variety of types being produced. Conveyancer Fork Trucks, Limited, Liverpool-road, Warrington, are showing several designs, both electrically and mechanically driven. Their latest battery model is the E3-20 which has a lifting capacity of 3,000 lb. at a 20-in. load centre. This truck is being shown fitted with the Skid-Stac attachment which replaces pallets, and an E3-20 truck fitted with this is shown in Fig. 3. The load is stacked on a sheet of fibre board, the edge of which is gripped by an hydraulic mechanism at the base of the rack. When the rack is retracted, also hydraulically, the fibre board is drawn on to a polished steel plate which replaces the forks of the truck. Thus, all the functions of a pallet are carried out by the fibre board, which can, if necessary, be regarded as an expendable item, and all the difficulties involved in the return of empty pallets are therefore avoided. Also on the stand is a number of working model trucks showing how attachments have increased versatility.

UTILISING STORAGE SPACE

A filing-system which only needs one gangway space for a large number of cabinets is being

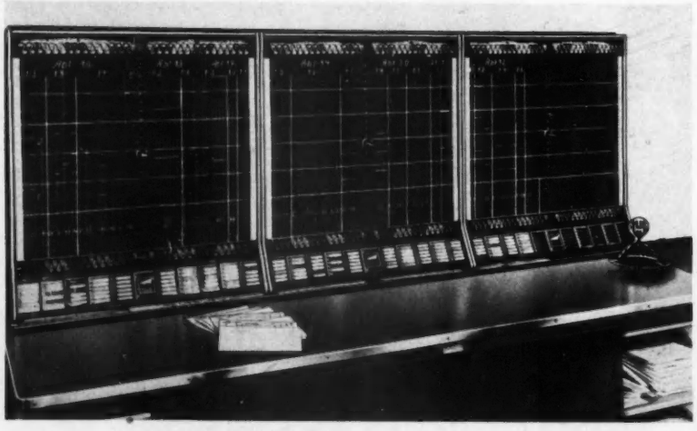

Fig. 2 The columns on Vidento progress charts, three of which are shown here, are built up from small balls, admitted or withdrawn by pressing a button. The Plexiglass face will take temporary notes.

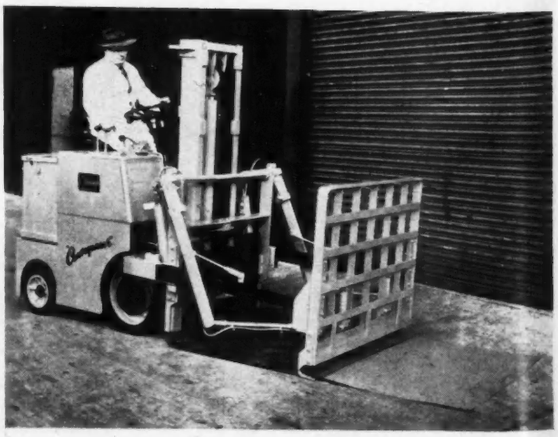

Fig. 3 The Skid-Stac attachment utilises a sheet of fibre board to draw the load on to the truck lifting plate, thereby avoiding the need for pallets.

Fig. 4 Storage space is increased by using racks which move to open gangways where required.

shown by J. Glover and Sons, Limited, Groton-road, Earlsfield, London, S.W.18. The system is the Auto-Mobile method of Compactus-Ingold, the distribution rights of which for this country have been granted to Glovers. An example of the layout is shown in Fig. 4. An electric motor drives a continuous belt running in channels in the floor, and deflecting the hand lever on the cabinet closes a clamp on the belt which then moves the cabinet or cabinets in the corresponding direction, giving a gangway at the required place. At the end of the day, all the cabinets are closed together, forming a dust-proof whole. The units, driven by a ¼-h.p. motor, move at a rate of 10 metres per minute and can be electrically controlled to open to the width of gangway required. The number of gangways to be opened can be selected at will, so that several people can work at the same time without risk of being trapped. When closed, the block can be locked from a central position. The use of the system is by no means confined to files, but can also be used for general storage of spare parts, even for items as large as pallets.

FIRE EXTINGUISHERS

Fire-fighting apparatus of some sort forms an essential part of the equipment of every factory, and the Pyrene Company, Limited, 9 Grosvenor-gardens, London, S.W.1, are showing a large range. Mention may be made of a dry-chemical extinguisher, the PDV 25, designed for the speedy smothering of liquid fires, especially those involving industrial solvents. The extinguisher contains 25 lb. of chemicals which are discharged by the pressure from a cylinder of carbon-dioxide. As the chemical is non-abrasive, non-corrosive and non-conducting, the extinguisher can be used on electrical apparatus. Operation is initiated by striking a plunger on the top cap, and the discharge is thereafter controlled by a squeeze-grip valve in the flexible hose. Recharging takes a matter of minutes only. Another recent addition to the firm's range of equipment is a foam-making branch-pipe which gives a foam output of 1,000 gallons per minute with a water pressure of 60 lb. per square inch, using 100 gallons of water and 5 gallons of foam compound. Discharge can be either as a spray or as a jet.

Fig. 5 The Autorex machine can fix from 25 to 40 labels a minute on flat round, oval or rectangular packages.

LABEL FIXING

The latest among the labelling machines being shown at the exhibition by Rawsons (Labelling Machines), Limited, 6 Church-road, Tunbridge Wells, is the Autorex Dry Precision labeller, which is an improved version of an earlier machine and is shown in Fig. 5. It is capable of applying "Heatfix" labels at rates between 25 and 40 a minute, to flat, round, oval or rectangular articles. The labels may cover one face only or extend right round the package.

In operation, a pair of combined suction and heater picker plates withdraw the label (which may be of any shape) from the adjustable storage box and place it on the package. Sufficient heat is applied during transit to activate the paper. When the label is in position, a finger grips it while the pickers are withdrawn, after which pressers complete the application of the label. The delayed-action Heatfix paper on which the labels are printed, will adhere to most metal or plastics surfaces. As no gum or adhesive is used, no time is needed for mixing beforehand, nor is there any need to clean the article after the label has been affixed. In fact it can be packed immediately it is removed from the machine.

COMBINED FORK TRUCK AND CRANE

Shelvoke and Drewry, Limited, Letchworth, Hertfordshire, are exhibiting their model 72 Freightlifter industrial fork truck, which can be converted to a crane. Driven by a 65-b.h.p. Diesel engine, the truck is 5 ft. wide and so can be used in most factory gangways. The lifting capacity is 12,000 lb. at 24 in. centre, reducing to 8,000 lb. at double this distance. The load carriage can be moved hydraulically 5 in. either side of the central position, which increases manœuvrability when handling wide loads, or when stacking. Using the telescopic masts, the truck has a maximum lift of 14 ft., in which position a headroom of 17 ft. 5 in. is required. When the masts are extended but the forks lowered the overall height is 10 ft. 10 in.

The truck also has hydraulically-assisted steering and servo-assisted braking, both of which add to the ease of handling. In less than five minutes the crane attachment can be fitted to the truck as shown in Fig. 6. This has a lifting capacity of 4¾ tons and requires very little headroom. Alternatively a single boom can be fitted in place of the forks, for handling coils or rolls of material; several other attachments are also available.

LIGHTWEIGHT HYDRAULIC JACKS

The most recent addition to the range of hydraulic equipment made by Tangyes, Limited, Smethwick, Birmingham, are the Hydralite jacks, examples of which are being shown. These are made in five models with lifting capacities ranging from 15 to 50 tons. Light alloys have been used as much as possible in the construction, with the result that weights range from 24 lb. to 61 lb. for the 50-ton model. The 15- and 25-ton sizes are available with lifts of either 6 or 12 in., but the 50-ton size is made with a lift of 6 in. only. Claw attachments are available. The 25-ton size with 12 in. lift is shown in Fig. 7. The jack is operated by a light-weight lever, 30 in. long, which can fit in any one of three sockets. Automatic breathers allow the jacks to be used both horizontally and vertically.

To be continued

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MATERIAL FOR ROAD MARKING

The Dunlop Rubber Company, Limited, St. James's House, St. James's Street, London, S.W.1, is now producing a flexible plastics material for marking pedestrian crossings and road lines generally. "Duvina," as it is called, is ⅛ in. thick and has a pyramid, or diamond-shaped surface to prevent skidding. Advantages claimed are its long life, its relative cheapness and the fact that it retains its whiteness. The surface reflects headlights up to 200 yards.

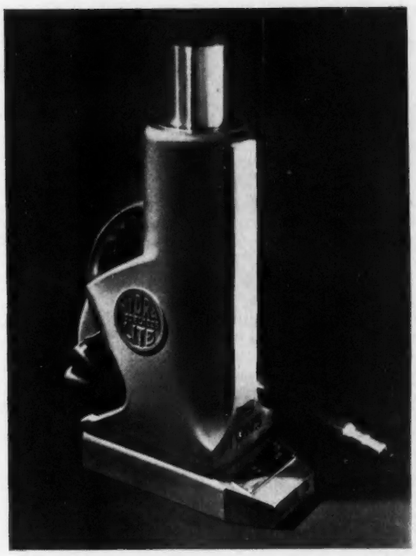

Fig. 7 Made from light alloys, the jack illustrated here weighs only 53 lb., but can lift 25 tons a height of 12 in.

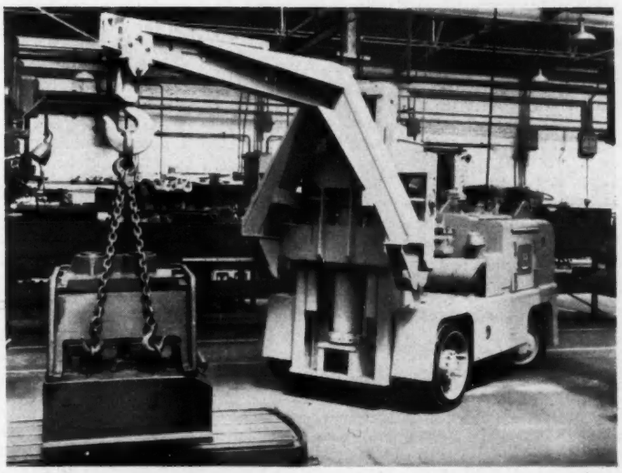

Fig. 6 This crane attachment, which has a lifting capacity of 4¾ tons, can be fixed to the fork-truck in less than five minutes.

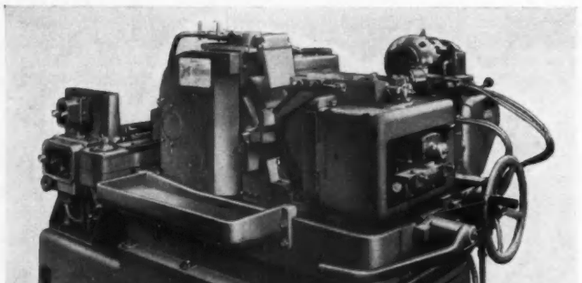

Fig. 1 The Scrivener centreless grinder is designed for straight-through grinding of parallel cylindrical work, but can also be used for plunge grinding under hand control.

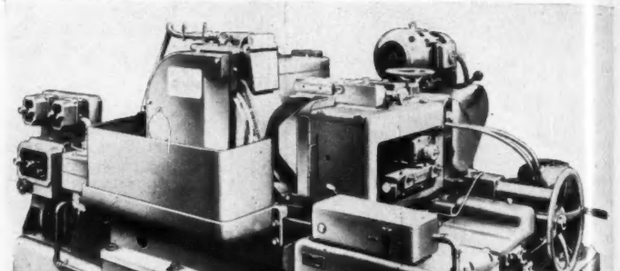

Fig. 2 For high-production plunge grinding an adaptation of the parallel machine is made. The wheel opening is controlled automatically by a cam-plate.

CENTRELESS GRINDING OF PARALLEL OR SHOULDERED WORK

AUTOMATIC CONTROLLED-CYCLE PLUNGE GRINDING

The machine shown in Fig. 1 herewith is the latest addition to the range of centreless grinders made by Arthur Scrivener Limited, Tyburn Road, Birmingham, 24. It is designed primarily for grinding parallel cylindrical work, which can be passed straight through between the wheels, and is particularly suitable for use with automatic feed equipment. The machine will grind cylindrical work from ¼ in. in diameter up to a maximum of 5 in. in diameter in the case of tubular components. Shouldered pieces, which could not pass between the wheels for straight-through grinding, can be ground by means of a hand-operated plunge-grinding mechanism. Taper and shallow-form work can be dealt with in the same way. For automatic plunge grinding an adaptation of the machine is available (Fig. 2) in which the advance of the control wheel and work is effected hydraulically under the control of a cam. The controlled-cycle machine has an output rate greatly in excess of anything which can be achieved by hand plunge grinding, and will handle deeply-formed work without difficulty.

The parallel-grinding machine is similar in principle to other Scrivener centreless grinding machines, but incorporates a number of improvements. The base is a heavy iron casting, which carries a bed, also of cast iron, giving great stability in operation. The control wheel is somewhat larger in diameter than in earlier models, and the drive to this wheel has been arranged from a single electric motor through a gearbox which provides the working and truing speeds.

The grinding wheel, which is 20 in. in diameter and 6 in. wide, runs at 1,000 r.p.m. It is carried on a Nitralloy-steel spindle running in plain phosphor-bronze bearings with forced-feed lubrication. An automatic safety device stops the machine if the oil supply to the bearings should fail. Endwise location of the grinding wheel is ensured by a collar immediately adjacent to the wheel and working with a ball thrust-race. Expansion of the spindle is permitted by a spring-loaded ball thrust-race at the rear end. The wheel is driven by V-belts from a 20-h.p. electric motor mounted in the base. The control wheel, 12 in. in diameter by 6 in. wide, is carried on a spindle similar to that used for the grinding wheel, and is driven by an independent motor of 1½ h.p. The bearings are lubricated by an independent pump. The control-wheel spindle can be set at any angle up to 7 deg. for feeding the work through the machine.

The workrest which carries the workplates is of the universal type, and is suitable for both straight-through and plunge grinding. The rest is coupled to the control wheel and moves with it; provision is made for adjustment of the rest in relation to the wheel. The workplates cover the whole range of work for which the machine is designed. They are supplied in two sets of nine: one set for straight-through grinding and the other for plunge grinding.

Form-truing attachments are provided for both wheels, the attachment for the control wheel being mounted on the fixed member of the control-wheel head. The slide and diamond thus always move in a horizontal plane effectively parallel with the grinding wheel, irrespective of the angular setting of the control wheel, and no adjustment is needed to allow for this setting. Both truing slides are hydraulically operated, the controls being at the front of the machine. For truing the grinding wheel the diamond is first advanced to the wheel, and the pointer of the control is set to the position marked "Grinding wheel." The diamond then travels across the face of the wheel at a rate which is controlled by a knob above the pointer. Truing of the control wheel is effected in a similar way, by setting the pointer to the opposite side of the dial. Hydraulic power is supplied to both slides by a pump fitted on the grinding-wheel head, and driven by a V-belt from the wheel spindle. This pump also supplies oil for lubricating the grinding-wheel spindle bearings.

The normal arrangement for adjusting the size of the component being ground is by a micro-feed attachment, which consists of a small handwheel on a vertical spindle coupled to the main lead screw through a worm, wheel and nut. The large handwheel controlling the lead screw is graduated in increments of 0·001 in., while the micro-feed handwheel is graduated to 0·0001 in. The setting of the machine for straight-through work and the making of adjustments during a run are thus rendered simple and accurate. As an extra attachment the automatic micro-sizer can be fitted. This attachment, which enables the fine-feed shaft of the machine to be rotated a pre-determined amount when a push-button is pressed, was described in ENGINEERING last December (vol. 178, page 837, 1954). It is built both for manual control by push-button and for fully-automatic control in conjunction with pneumatic measuring equipment.

CONTROLLED-CYCLE PLUNGE GRINDING

Plunge grinding of shouldered work can be done under hand control on a centreless grinder of the type described, but there are certain limitations imposed by the design of the machine. In addition, since the operation is under manual control, there is a risk of error, and the fatigue factor has to be taken into account when considering output rates. To overcome these difficulties an adaptation of the straight-through machine has been designed. Basically, the operation of plunge grinding involves closing the gap between the wheels to perform the grinding

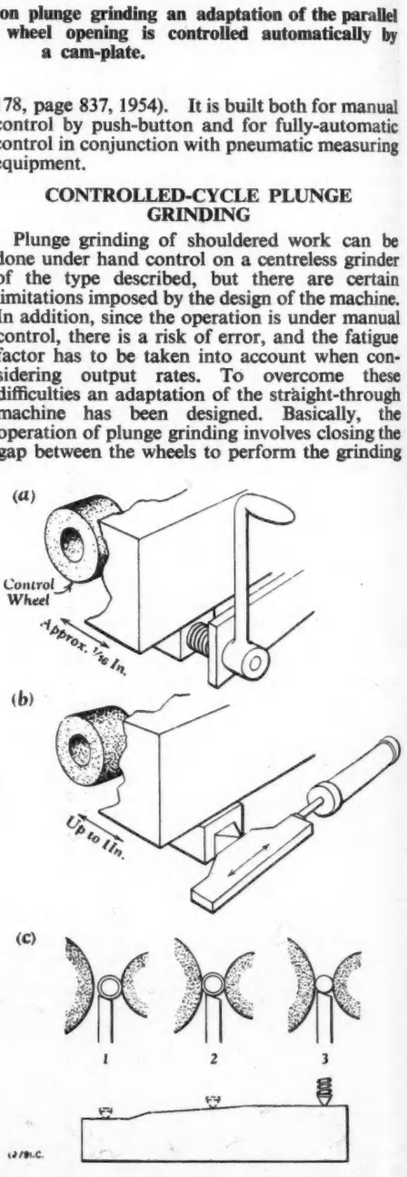

Fig. 3 Sketch (a) shows diagrammatically the hand control of plunge grinding, (b) shows it controlled by a cam-plate. The cycle is indicated by sketch (c).

of the component, and then opening the gap to allow the piece to be ejected. This can be done under hand control, as shown diagrammatically in Fig. 3(a), or, as in the controlled-cycle machine, by a cam-plate which is reciprocated hydraulically. Fig 3(b) shows this arrangement, and Fig. 3(c) shows the operational cycle. In position 1 the wheels are at the maximum opening, ready to receive a workpiece. This gap can be up to 1 in. In position 2 the follower is mounting the grinding slope of the cam-plate and grinding is in progress. In position 3 grinding has been completed, and the follower is on a short flat length of the cam-plate, giving a brief final "dwell" of the wheel on the piece. After this, the piece is ejected and the cam-plate returns to its starting position at twice its forward speed. The grinding cycle is fully automatic. All the operator has to do is to place the piece in position and turn a small lever controlling the hydraulic cylinder which moves the cam-plate. It is possible to convert the machine to completely automatic operation by using a suitable hopper or magazine, many different types of which are available as extra equipment.

Both machines are supplied complete with a range of necessary equipment, including grinding and control wheels, work rests, guide plates and built-in coolant tank and pump. Only the electrical equipment is left to be fitted on site to suit the available current supply. This equipment can, however, be fitted at the maker's works if specially ordered. There is also available a wide range of extra fittings for special purposes, including a crush-forming unit, work ejectors, work chutes and through-feed conveyor.

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LAUNCHES AND TRIAL TRIPS

M.S. "HAVDROTT."—Twin-screw oil tanker, built and engined by Eriksbergs Mek. Verkstads Aktiebolag, Gothenburg, Sweden, for Meyers Tankrederi A/S, Oslo, Norway. Fifth vessel constructed for these owners. Main dimensions: 659 ft. 3 in. overall by 86 ft. by 45 ft. 9 in.; deadweight capacity, 32,000 tons on a summer draught of about 34 ft.; oil-tank capacity, 1,560,000 cub. ft. Two Eriksbergs- B. & W. six-cylinder single-acting two-stroke Diesel engines, together developing 13,800 i.h.p. Speed, 15½ knots fully loaded. Launch, March 10.

M.S. "PORT MELBOURNE."—Twin-screw cargo vessel, with accommodation for twelve passengers, built and engined by Harland and Wolff, Ltd., Belfast, for the Port Line Ltd., London, E.C.3. Main dimensions: 498 ft. between perpendiculars by 70 ft. by 42 ft. to upper deck; gross tonnage, about 9,800. Two Harland-B. and W. six-cylinder single-acting two-stroke oil engines, arranged to burn heavy oil, with Diesel oil as an alternative. Launch, March 10.

M.S. "ST. BARTHOLOMEW."—Single-screw trawler, built by Cook, Welton and Gemmell, Ltd., Beverley, Yorkshire, to the order of St. Andrews Steam Fishing Co., Ltd., Hull, and the Boston Deep Sea Fishing and Ice Co., Ltd., Fleetwood. Second of three trawlers built under the auspices of the White Fish Authority's construction scheme. Main dimensions: 152 ft. 3 in. overall by 28 ft. by 13 ft. 9 in.; gross tonnage, about 390; fishroom capacity, 9,300 cub. ft. Six-cylinder marine Diesel engine, developing 850 b.h.p. at 250 r.p.m., constructed by British Polar Engines, Ltd., Glasgow, and installed by Amos and Smith, Ltd., Hull. Launch, March 12.

M.S. "VICTORIA CITY."—Single-screw cargo vessel, built and engined by William Doxford and Sons, Ltd., Sunderland, for Sir William Reardon Smith and Sons, Ltd., Cardiff. First vessel of a series of four. Main dimensions: 436 ft. 6 in. between perpendiculars by 59 ft. 2½ in. by 28 ft. 8 in.; deadweight capacity, about 9,300 tons on a draught of 25 ft. 5½ in. Doxford four-cylinder opposed-piston oil engine, developing 4,000 b.h.p. at 100 r.p.m. Speed, about 13½ knots. Trial trip, March 15.

S.S. "CORSTREAM."—Single-screw collier, built by the Burntisland Shipbuilding Co., Ltd., Burntisland, Fife, for William Cory and Son, Ltd., London, E.C.3. Main dimensions: 320 ft. between perpendiculars by 46 ft. by 22 ft. 4 in.; deadweight capacity, about 4,600 tons on a draught of 20 ft. Direct-acting triple-expansion steam engine of reheat design, developing 1,100 i.h.p. in service, constructed by the North Eastern Marine Engineering Co. (1938), Ltd., Sunderland. Steam supplied by two multitubular oil-burning boilers. Launch, March 22.

PRODUCING CORED STAMPINGS ON A HOT-BRASS PRESS

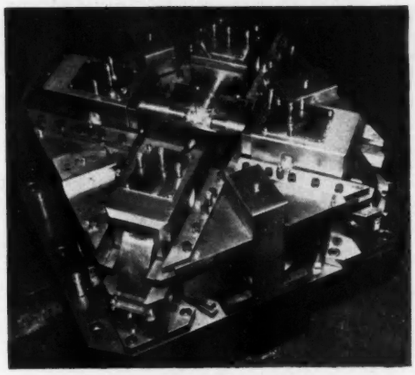
Detachable Sub-Press Unit

The straightforward hot-brass stamping press will produce a large variety of simple stampings, but if multi-cored components are required it is necessary to use a side-action press. To adapt their standard press for cored work, Wilkins and Mitchell, Limited, Darlaston, South Staffordshire, have designed a detachable sub-press unit. It can be attached to the standard hot-brass press quickly, and it will enable the machine to carry out the same work as a side-action press. In addition it is able to core in two planes.

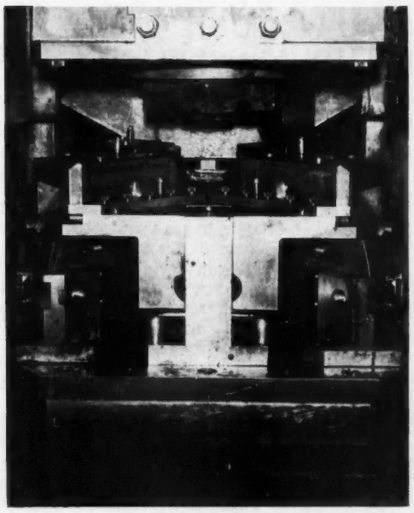
The sub-press unit consists basically of a heavy square die-holder with a die-space of 6 or 8 in. This die-holder is supported on the pneumatic cushion of the parent press by means of pressure-pins passing through the press bed. Spaced round the die-holder are horizontally-mounted slides, the inner faces of which have machined recesses to suit the bases of the working punches. Retaining plates are provided to hold the punches in position by means of recessed socket screws. The slides are coupled to short compression levers pivoted in the die-holder and operated from pedestals attached to the press bed. The complete unit ready for mounting, is shown in the first illustration. The second shows it in place, supported on the pressure pins, and with the punches withdrawn. The pivoted compression levers can be clearly seen. The third shows the billet space available.

At the commencement of a working stroke the die-holder is held up by the pneumatic cushion and, as the compression lever pedestals are attached to the press bed, the levers are drawn back and the slides are retracted to their extreme outer position. The punches carried on the slides are thus withdrawn from the bottom die, and a clear space is left for insertion of the hot billet by the operator in the normal way. As the press makes its working stroke the dies are closed, and the pressure forces the die-holder against the pneumatic cushion, thus operating the compression levers and bringing the punches forward to produce the cored holes in the component. On the return stroke the pneumatic cushion rises, the punches are withdrawn by the compression levers, and the dies open to allow the stamping to be removed.

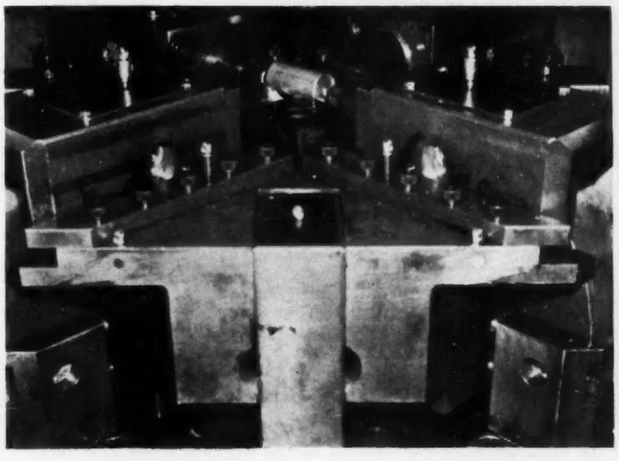
The stroke of the slides carrying the punches is variable up to a maximum of 4 in., and can be adjusted to suit the depth of cored hole required. Several modifications of the sub-press unit are possible. The standard model has four slides and it is possible to produce four cored holes in the horizontal plane in addition to two in the vertical plane. More than four cored holes can be made if required by modifying the sub-press suitably, and components with seven cored holes have, in fact, been made on the unit. Alternatively, one or more of the punches can be omitted if a smaller number of cored holes is required. Simple cores, which come into place before the dies close, and are not driven into the plastic metal in the same way as the punches, can be introduced in place of a working punch in any of the four positions in the sub-press when required. These cores are operated by wedges carried on the press slide.



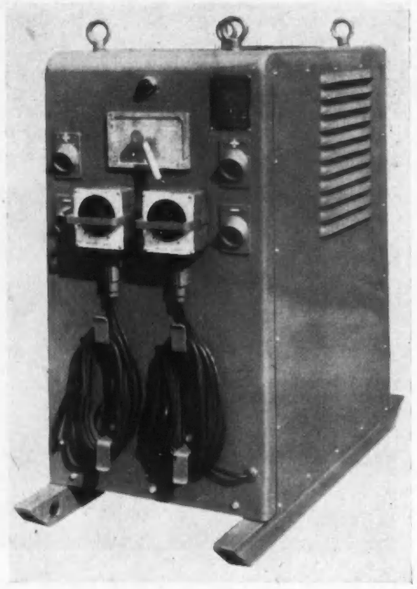
The Wilkins and Mitchell sub-press can be fitted to one of the firm's standard hot-brass stamping presses to adapt it to produce multi-cored work. The unit is shown here before mounting on the press bed.



The sub-press is supported on the pneumatic cushion of the press by pressure-pins.



Ample space is available for insertion of the heated billet before the dies close.



This power unit can be used for stud welding of studs up to 2 in. in diameter, or alternatively for two arc-welding operations with independent remote control.

POWER UNIT FOR BOTH STUD AND ARC WELDING

Choice of Three Outputs

A transformer-rectifier power unit has recently been introduced by Crompton Parkinson Limited, Crompton House, Aldwych, London, W.C.2, which has been developed to meet the requirements of stud welding and arc welding. Its appearance is shown in the illustration above.

The unit provides a choice of three outputs: one for stud welding up to ½-in. diameter studs; another for single-operator arc-welding with current up to 400 amperes; and a third for two independent arc-welding operators using up to 200 amperes each. Selection of output is accomplished by means of a three-position switch and facilities are provided for independent remote control of arc welding currents.

The new power source consists basically of a 3-phase air-cooled transformer which is suitable for input voltages of 210-250 volts and 360-440 volts and for operation on a 40-100 cycle supply; two banks of selenium rectifiers which operate either in parallel or independently according to the position of the selector switch; and two magnetic amplifiers which facilitate fine control of current when the equipment is used for arc-welding. This latter feature, in conjunction with two continuously variable rheostats connected by 20 ft. of cable, enables the operator to adjust the current at the point of welding.

The rectifier, transformer and other internal components are maintained at a safe operating temperature by means of a totally enclosed cooling fan. Incorporated with the fan is a centrifugally operated switch which, if the motor ceases to operate for any reason, automatically interrupts the exciter supply, thereby reducing the output to a safe level.

Other features include the so-called "hot-start" that is, a 25 per cent. current increase which occurs momentarily at the commencement of arc-welding and provides for easy striking of the arc, and the fact that the unit is a non-inductive power source with the result that its current recovery time is comparable with that of an arc-welding transformer.

All components are contained in a rustproof metal housing and have been designed electrically and mechanically to withstand extremes of temperature, thus rendering the unit suitable for use in both tropical and arctic conditions. It is 4 ft. in height, 3 ft. 10 in. in depth and 2 ft. 0½ in. in width. The gross weight is 11½ cwt. Because of the provision for remote control it is not necessary to have this power source close to the point of welding.

* * *

WORKING A 98-IN. MIRROR

Grinding and Testing Mirror for the Isaac Newton Telescope

From a paper which Mr. G. M. Sisson, of Sir Howard Grubb, Parsons and Company, Newcastle-upon-Tyne, delivered at a meeting of the Royal Society on Thursday, February 10, we give below some extracts from the section of it relating to the production of the 98-in. mirror for the Isaac Newton telescope which is to be set up at Herstmonceux. The mirror is spherical in form with a radius of curvature of 588 in. (49 ft.), as it is to be used with an 80-in. correcting plate to form the most powerful Schmidt camera in the world.

The glass disc, of Pyrex, was cast in the United States in 1936 and presented to the Astronomer Royal in 1949. It was sent to the Walker Gate works for grinding and figuring in 1950. As received, the disc was filled with a mass of cords and veins which precluded the usual preliminary examination by polarised light. One of the cords, about 1 in. in diameter, had broken up to form a set of closely-spaced orthogonal cracks, called in the works the "Diamond Tiara." After the work of truing up the disc with diamond cutting tools had been carried on for some weeks it was found that a new system of cracks had appeared which had extended to the surface and continued to extend for about two weeks after the work had been stopped. It was then decided to leave the disc for at least a year to settle down.

The work was resumed by the slower method of grinding with silicon-carbide abrasive instead of the diamond cutters, but even so the cracks extended further and fresh ones appeared. This would have been very serious in the subsequent polishing process, but trouble was avoided by filling the cracks with cold-setting Araldite resin by local vacuum impregnation. During polishing, the mirror was supported on 540 rubber blocks and the operation was successfully completed. Fig. 1 shows the disc set up on edge ready for testing. The central hole, present in the disc as received, will be noticed.

In the testing of large mirrors three factors of decisive importance have to be considered, namely, temperature, air conditions and method of support. In general, a horizontal test tunnel is used in the Walker Gate works, but air turbulence and stratification cause certain difficulties and a vertical test tower would have many advantages in the case of a mirror as large as 98 in. in diameter. When the figuring of this mirror had proceeded to the stage at which it was considered that no errors exceeding $1{\cdot}5 \times 10^{-6}$ in. existed, a prolonged series of final tests was commenced and then an interesting, but unexpected trouble became apparent: the surface of the mirror started to change its general shape and over a period of about three months a change amounting to about 5×10^{-6} in. was observed. The four upper curves in the graph, Fig. 2, show how the errors developed in this period of constant temperature.

It is, of course, well known that glass is visco-elastic, but it was hardly expected that appreciable changes in dimensions would take place over a period of more than about a week following a disturbance of the strain symmetry such as occurs when one side is hollowed out to form the concave mirror face. It was therefore decided to put the mirror into storage and test it lying on its back during the holiday period when a vacuum impregnating pit for large alternators, in the Heaton Works, could be made available for a few days. The pit is 30 ft. deep and a platform 20 ft. high was erected above it. The mirror was laid in the bottom of the pit, supported on a rubber bag 90 in. in diameter, which is probably the largest air cushion ever made. A long canvas tube from the platform to the mirror excluded draughts. The tests then made confirmed that the mirror was free from significant astigmatism, a point which had been very difficult to settle conclusively in the horizontal tunnel. As, however, there was no possibility of temperature control in the pit, no conclusion could be reached about the actual figure of the mirror. The five lower curves in the graph, Fig. 2, were obtained while the mirror was in the pit and show how sensitive the figure is to changes in ambient temperature.

It is now being tested again in the tunnel under controlled conditions; these tests will show by how much its shape has been permanently changed and if it is still changing. As soon as it proves stable it will be re-worked, if necessary.

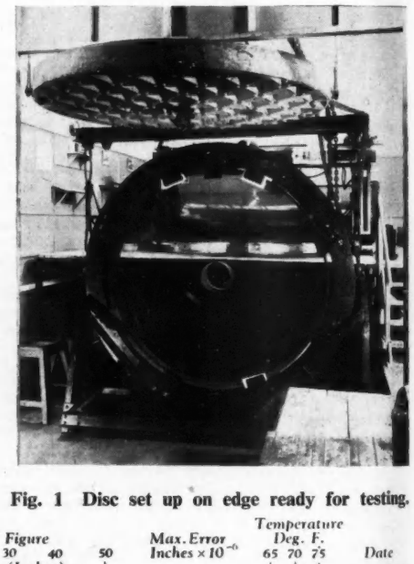


Fig. 1 Disc set up on edge ready for testing.

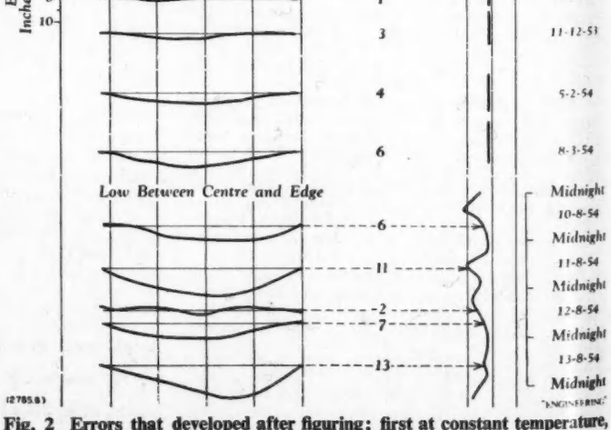


Fig. 2 Errors that developed after figuring; first at constant temperature, and subsequently without temperature control.

Labour Notes

SCARCITY OF LABOUR

Pressure on the nation's manpower resources is likely to continue throughout the present year. Although it is officially expected that there will be some further increase in the working population of Great Britain in the coming months, a warning is given in the March issue of the Treasury's *Bulletin for Industry*, published last week, that industrialists cannot count on as large an increase as last year, or on any sharp rise in working hours.

Any further advances in productivity must accordingly come largely from increased output per man-hour. This conclusion underlines the importance attached to re-organisation schemes, work study, mechanisation, joint consultation, and similar arrangements, by which efficiency and production can be improved still more without increasing demands on scarce labour supplies.

The shortage of labour also stresses the importance of placing new projects with heavy manpower requirements in areas where the pressure on labour supplies is least.

Figures quoted by the Treasury, as indicative of the increasing demands on the nation's manpower requirements, show that the number of vacancies unfilled at employment exchanges, in February last, was 36 per cent. higher than a year previously.

TREND OF EMPLOYMENT

The rise in industrial productivity by 6 per cent. in 1954, was due partly to higher output per individual and partly to an increase in employment. It is noteworthy that, according to the Treasury's *Bulletin*, two-thirds of the rise in production was contributed by the former cause.

Persons in civil occupations last year increased in number by 350,000, equivalent to about 1½ per cent. of the total number of people so engaged. It was the largest increase in any year since 1947. The most spectacular change took place in the manufacturing industries, which found employment for some 258,000 more workpeople.

About 177,000 of this total went into the engineering, metals, and vehicle-building group of industries: the vehicle-manufacturing and electrical-goods industries being the ones which benefited most. There were smaller gains in some other manufacturing industries and minor declines in employment in the textile and clothing industries.

Outside the manufacturing section, the largest changes were a rise of 77,000 persons in employment in the distributing industry, and declines of about 20,000 persons each in the transport and agricultural industries.

Short-time worked in manufacturing industries last year was negligible and affected only one operative in every 200, but overtime continued to increase, especially in the engineering, metals, and vehicle-building group. In the concluding week of November, 1954, some 28½ per cent. of all operatives in manufacturing industries were working overtime.

LONDON NEWSPAPER STRIKE

Electricians and maintenance men employed on the staffs of the London national newspapers came out on strike as from last Friday morning, with the result that the three London evening newspapers were compelled to cease publication as from that evening, and the London morning newspapers as from last Saturday. London Sunday newspapers were also affected. The dispute arose out of a wage claim.

The men, of whom several hundred are employed in the newspaper offices concerned, belong to the Electrical Trades Union and the Amalgamated Engineering Union. They are not affiliated to the Printing and Kindred Trades Federation, as are other printing-trade operatives, through their individual unions, but it has been usual for the electricians and maintenance men to receive similar advances in their basic rates of pay to those conceded to members of the printing unions.

An announcement issued before the strike by the Newspaper Proprietors' Association, of which the newspapers concerned are members, declared that an offer of a wage increase, identical to that made to all other unions in the London newspaper-printing industry, and accepted by a majority of them, had been refused by the Electrical Trades Union and the Amalgamated Engineering Union. The employers had offered to submit the case to arbitration but that suggestion also was refused.

Efforts were made by the two unions during negotiations on the recent series of wage claims in the newspaper industry to improve the position of their members in relation to that of other printing-trade operatives. The unions argued that the rates paid to their members did not adequately compensate for the men's services and skill. They also contended that it was not sufficient for their members' rates merely to keep pace with those obtaining in other branches of the industry.

INCREASES OFFERED

A statement issued by the Newspaper Proprietors' Association on Sunday emphasised the willingness of the Association to meet representatives of the two unions to discuss any points arising in connection with the dispute, except the amount of the Association's wage offer, subject to resumption of work. It was the non-acceptance of that offer which led to the strike.

Almost simultaneously, an announcement was made by the London district secretary of the A.E.U. declaring that the strikers' officials were ready to meet representatives of any individual newspaper to negotiate a settlement with them.

The basic weekly rates for skilled electrical and engineering craftsmen in the London area on October 31, 1954, were £12 5*s.* for employees engaged on night work and £10 9*s.* 6*d.* for men on day work, in each case including a cost-of-living bonus of 21*s.* These men were offered £12 19*s.* 6*d.* a week for night work and £11 1*s.* 6*d.* a week for day work, both inclusive of a fixed bonus.

The new rates offered by the employers for semi-skilled operatives were £10 13*s.* 6*d.* for night workers and £9 17*s.* 6*d.* for day workers, including a fixed bonus. It is understood that the unions are asking for another £2 18*s.* 6*d.* a week, which would raise the men's rates to about 125 per cent. above their pre-war level.

The strike is the second dispute to affect the publication of London newspapers during recent months. In mid-October last, the issue of most editions of the main national daily and evening newspapers was stopped for one day owing to an inter-union dispute regarding machine-minding arrangements at one newspaper-printing establishment.

MORE PAY FOR ORDNANCE EMPLOYEES

Certain grades of industrial operatives employed at Royal Ordnance Factories and at other Government establishments in Britain are to receive advances in their basic rates of pay, according to a wage settlement reached on March 23.

The increases granted will be in line with those for adult male employees in the engineering industry agreed to between the Engineering and Allied Employers' National Federation and the Confederation of Shipbuilding and Engineering Unions earlier this month.

Skilled craftsmen will obtain an extra 11*s.* a week, labourers an additional 8*s.* a week, and semi-skilled men in the intermediate grades an increase of 9*s.* 6*d.* a week.

At the negotiations before the Engineering Trades Joint Council on March 23, the trade-union side of the Council pressed the official representatives for increases of 15*s.* a week for engineering craftsmen and of 10*s.* a week for the unskilled grades.

The union representatives are understood to have drawn special attention to recent views on what constitutes "fair wages" in particular industries. They are believed to have protested about the official side's interpretation of the "fair wages" clause in the agreement applicable to rates of pay at Government industrial establishments.

The increases are to be back-dated to March 14, and are expected to benefit about 64,000 employees. The Admiralty is understood to have made a similar offer in respect of its industrial operatives.

PUBLIC CONTROL IN ENGINEERING

There are signs that the General Council of the Trades Union Congress may undertake in the near future a thorough examination of the existing possibilities of nationalisation.

This question is understood to have come up for consideration at the Council's monthly meeting on March 23, when it was resolved to ask the Confederation of Shipbuilding and Engineering Unions whether it was prepared to carry on the joint discussions on the future organisation of some sections of the engineering industry.

Discussions with the Confederation on its *Plan for Engineering* were discontinued after the Labour Party's conference in 1953, at which, it may be recalled, Mr. Arthur Deakin, the general secretary of the Transport and General Workers' Union, condemned the plan and described it as "a mumbo-jumbo of meaningless words and phrases."

It was in 1953 that the Council issued their own interim report on public ownership, which had special reference to certain sections of the engineering industry. In this document, the Council expressed the view that the machine-tool trade might benefit from some form of joint research and sales organisation, operating with Government assistance, and that a development council should be set up for the shipbuilding industry. They suggested that the advantages of such proposals should be fully examined with the assistance of the Confederation.

UNIONS' VIEWS ON RAILWAY PLAN

The British Transport Commission's scheme for the modernisation of the railways was also discussed at the Council's meeting; particular attention being given to the manpower problems involved.

In this connection, the Council expressed the opinion that inadequate recognition was given in the plan to the need for close co-operation with the trade unions having members in the railway industry.

Nevertheless, the Council considered, that the Commission and the railway unions could, by accepting their responsibilities in a spirit of mutual co-operation, secure the results which the plan sought to achieve. The Council welcomed the plan but emphasised that good industrial relations were essential to success.

NOTICES OF MEETINGS

Association of Supervising Electrical Engineers

LONDON
"Modern Lift Practice," by S. T. Elvey. West London Branch. 134 King-street, Hammersmith, W.6. Tues., April 5, 7.30 p.m.

CROYDON
"Some Notes on Electrical Safety," by H. W. Swann. South London Branch. Café Royal, North End, Croydon. Thurs., April 7, 8 p.m.

ELTHAM
Film Evening. South-East London Branch. Congregational Church, Court-road, Eltham. Tues., April 5, 8 p.m.

LEEDS
Open Meeting. Leeds Branch. Great Northern Hotel, Leeds. Mon., April 4, 7 p.m.

PORTSMOUTH
Discussion on "Industrial Lighting." Portsmouth Branch. 598 Commercial-road, Mile End, Portsmouth. Tues., April 5, 7.30 p.m.

PRESTON
"Power Factor Improvement," by T. S. Smith. Preston Branch. Preston Chamber of Commerce, 49A, Fishergate, Preston. Wed., April 6, 7.30 p.m.

British Institution of Radio Engineers

LONDON
Discussion on "The B.B.C. Very-High-Frequency Sound Broadcasting Service," opened by Dr. K. R. Sturley and F. T. Lett. London Section. London School of Hygiene and Tropical Medicine, Keppel-street, W.C.1. Wed., April 13, 6.30 p.m.

GLASGOW
Film Evening and Exhibition of Electronics Apparatus. Scottish Section. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Thurs., April 14, 7 p.m.

NEWCASTLE-UPON-TYNE
"Manchester University Electronic Computer," by E. T. Warburton. Annual Meeting. North-Eastern Section. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Wed., April 13, 6 p.m.

Chemical Society

ST. ANDREWS
"Polymerisation of the Vinyl Ethers," by Professor D. D. Eley. St. Andrews and Dundee Branch. Chemistry Department, The University, St. Andrews. Fri., April 15, 5.15. p.m.

Engineers' Guild

LONDON
"Interplanetary Travel," by Dr. G. S. Brosan. Metropolitan Branch. Caxton Hall, Westminster, S.W.1. Thurs., April 14, 6 p.m.

Illuminating Engineering Society

CARDIFF
"Black Light: Its Effects and Applications," by H. L. Privett. Cardiff Centre. Offices of the South Wales Electricity Board, The Hayes, Cardiff. Thurs., April 7, 5.45 p.m.

EDINBURGH
Annual General Meeting and Film Evening. Edinburgh Centre. Manor Club, 12 Rothesay-place, Edinburgh, 3. Wed., April 6, 7 p.m.

NEWCASTLE-UPON-TYNE
Annual General Meeting. Newcastle Centre. Liberal Club, Pilgrim-street, Newcastle-upon-Tyne. Wed., April 6, 6.15 p.m.

NOTTINGHAM
"Compromise in Lighting-Fittings Design," by J. Studholme. Nottingham Centre. Offices of the East Midlands Electricity Board, Smithy-row, Nottingham. Thurs., April 7, 6 p.m.

SWANSEA
"Black Light: Its Effect and Applications," by H. L. Privett. Swansea Group. Offices of the South Wales Electricity Board, The Kingsway, Swansea. Wed., April 6, 6.30 p.m.

Incorporated Plant Engineers

LONDON
"Application of Gas Turbines to Industrial Duties," by G. B. R. Feilden. London Branch. Royal Society of Arts, John Adam-street, W.C.2. Tues., April 5, 7 p.m.

LEICESTER
"Use of Electrical Equipment in the Hosiery Industry," by E. W. Freeman. Leicester Branch. Leicester College of Art and Technology, The Newarkes, Leicester. Wed., April 6, 6.30 p.m.

PETERBOROUGH
Discussion on "Lubrication." Peterborough Branch. Campbell Hotel, Bridge-street, Peterborough. Thurs., April 7, 7.30 p.m.

SOUTHAMPTON
Brains Trust Meeting. Southampton Branch. Polygon Hotel, Southampton. Wed., April 6, 7.30 p.m.

Institute of British Foundrymen

LUTON
"Non-Ferrous Castings," by H. Thompson. Bedfordshire and Hertfordshire Section. Town Hall, Luton. Thurs., April 14, 7.30 p.m.

Institute of Fuel

NEWCASTLE-UPON-TYNE
Address by the Institute President, Dr. W. Idris Jones. North-Eastern Section. King's College, Newcastle-upon-Tyne. Mon., April 11, 6.30 p.m.

Institute of Metals

LONDON
Annual General Meeting, 6 p.m. Discussion on "Recent Developments in Special Machining Techniques," 6.30 p.m. London Local Section. Thurs., April 14.

BIRMINGHAM
Annual General Meeting. Birmingham Local Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., April 7, 6.30 p.m.

Institute of Petroleum

LONDON
"Refining Methods for Maximising Middle Distillate Production," by L. S. Bonnell. Wed., April 13, 5.30 p.m.

Institute of Road Transport Engineers

CAMBRIDGE
Annual General Meeting. Eastern Centre. Lion Hotel, Cambridge. Wed., April 6, 7 p.m.

CARDIFF
Discussion on "Ford Diesel Engines." South Wales Group. South Wales Institute of Engineers, Park-place, Cardiff. Thurs., April 14, 7 p.m.

GLASGOW
"Roads and Commercial Transport," by Dr. G. Charlesworth. Scottish Centre. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow, C.2. Mon., April 4, 7.30 p.m.

NOTTINGHAM
"Gas Turbines and Their Application to Road Transport," by A. Enticknap. East Midlands Centre. Mechanics' Institute, Nottingham. Wed., April 6, 7.30 p.m.

WIGAN
Annual General Meeting. North-Western Centre. Minorca Restaurant, Wigan. Wed., April 13, 7.30 p.m.

Institute of Welding

CHATHAM
Annual General Meeting. South London (Medway) Section. Sun Hotel, Chatham. Wed., April 6, 7.45 p.m.

LIVERPOOL
Annual General Meeting and Film Evening. Liverpool Branch. College of Technology, Byrom-street, Liverpool. Tues., April 5, 7.15 p.m.

MANCHESTER
Annual General Meeting and Film Evening. Manchester Branch. College of Technology, Sackville-street, Manchester. Wed., April 6, 7.15 p.m.

MIDDLESBROUGH
Annual General Meeting and Film Evening. North-Eastern (Tees-Side) Branch. Cleveland Scientific and Technical Institution, Corporation-road, Middlesbrough. Thurs., April 7, 7.30 p.m.

NOTTINGHAM
Annual General Meeting and Film Evening. East Midlands Branch. Victoria Station Hotel, Nottingham. Tues., April 5, 7.15 p.m.

PORTOBELLO
Annual General Meeting and Demonstration Night. East of Scotland Branch. Ramsey Technical College, Portobello. Wed., April 6, 7 p.m.

Institution of Chemical Engineers

CHESTER
"Engineering in Chemical Plants," by O. W. Murray. North-Western Branch. Grosvenor Hotel, Chester. Wed., April 13, 7 p.m.

MANCHESTER
"Researches into Factors Affecting the Performance of Electro-Precipitators," by J. R. A. Lakey and W. Bostock. North-Western Branch. College of Technology, Sackville-street, Manchester. Sat., April 16, 3 p.m.

Institution of Civil Engineers

LONDON
"Some Hydraulic Aspects of Sewerage and Sewage Disposal," by C. B. Townend and G. W. Wilkinson. Hydraulics Engineering Division. Tues., April 5, 5.30 p.m.

BIRMINGHAM
"Model Experiments on the Storm of 1953 in the Thames Estuary and the Reduction of Future Surges," by Sir Claude Inglis and F. H. Allen. Midlands Association. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., April 14, 6 p.m.

HULL
"Reconstruction of No. 12 Quay, King George Dock, Hull," by C. J. Frank. Annual General Meeting. Yorkshire Association. Offices of the Yorkshire Electricity Board, Ferensway, Hull. Wed., April 13, 6.15 p.m.

Institution of Electrical Engineers

LONDON
"High-Speed Electronic-Analogue Computing Techniques," by Dr. D. M. MacKay. Joint Meeting of the Measurements and Radio Sections. Tues., April 5, 5.30 p.m.

GLASGOW
"Aluminium Sheathed Cables," by P. M. Hollingsworth and P. A. Raine. Scottish Centre. Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank-crescent, Glasgow. Wed., April 6, 7 p.m.

LIVERPOOL
"Special Effects for Television Studio Productions," by A. M. Spooner and T. Worswick. Annual General Meeting. Mersey and North Wales Centre. Royal Institution, Colquitt-street, Liverpool. Mon., April 4, 6.30 p.m.

MANCHESTER
"Electrical Energy from the Wind," by E. W. Golding. North-Western Centre. Engineers' Club, Albert-square, Manchester. Tues., April 5, 6.15 p.m.

PORTSMOUTH
"Modern Developments in Atomic Energy," by Dr. T. E. Allibone. Annual General Meeting. Southern Centre. Chamber of Commerce, 46 Commercial-road, Portsmouth. Wed., April 13, 6.30 p.m.

YORK
"Possibilities of a Cross-Channel Power Link Between the British and French Supply Systems," by D. P. Sayers, M. E. Laborde and F. J. Lane. North Midland Centre. Royal Station Hotel, York. Tues., April 5, 7 p.m.

Institution of Engineering Designers

NEWCASTLE-UPON-TYNE
Films on "Diesel Engines and Aeronautics." North-East Branch. Northern Architectural Association, 6 Higham-place, Newcastle-upon-Tyne. Thurs., April 7, 7.15 p.m.

Institution of Heating and Ventilating Engineers

LONDON
Discussion on "What Fuel Should I Use?" Junior Institution of Engineers, 14 Rochester-row, Westminster, S.W.1. Tues., April 5, 6 p.m.

LEICESTER
Annual General Meeting. East Midlands Branch. Grand Hotel, Leicester. Wed., April 6, 6.30 p.m.

Institution of Mechanical Engineers

LONDON
"Matching a Diesel Engine to Light Road Vehicles," by N. Vulliamy; "Some Aspects of the Design and Performance of Small Diesel Engines," by B. W. Millington and M. H. Howarth; and "Fuel Requirements of the Small Automotive High-Speed Diesel Engine," by G. M. Barrett and H. G. Freeston. Automobile Division. Tues., April 5, 5.30 p.m.
Discussion Meeting. Hydraulics Group. Wed., April 6, 6.45 p.m.

BRISTOL
"Development and Scope of Work Study," by R. M. Currie. Western Branch. University Physics Theatre, Royal Fort, Bristol. Tues., April 5, 7 p.m.

Institution of Production Engineers

LONDON
Annual General Meeting and Film Evening. London Graduate Section. Tues., April 5, 7.15 p.m.

HALIFAX
"Production of Modern Electric Washing Machines," by J. Senior. Halifax Section. Collinson's Café, Crown-street, Halifax. Wed., April 6, 7.30 p.m.

Institution of Railway Signal Engineers

LONDON
Annual General Meeting. Institution of Electrical Engineers, Savoy-place, Victoria-embankment, W.C.2. Wed., April 13, 6 p.m.

Institution of the Rubber Industry

BURTON-ON-TRENT
Annual General Meeting and Film Evening. Burton-on-Trent Section. Midland Hotel, Station-street, Burton-on-Trent. Mon., April 4, 7.15 p.m.

NEWCASTLE-UPON-TYNE
Annual General Meeting. North-Eastern Section. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., April 4, 7 p.m.

Junior Institution of Engineers

BIRMINGHAM
Discussion on "Machine Tools: Historical Development and Future Trends." Midland Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Wed., April 6, 7 p.m.

SHEFFIELD
Repetition of Presidential Address on "Engineering in the Twentieth Century," by Professor S. J. Davies. Sheffield Section. Royal Victoria Hotel, Sheffield. Tues., April 5, 7.30 p.m.

London Association of Engineers

LONDON
"Overall Picture of the National Physical Laboratory," by A. J. Garrett. Alliance Hall, Palmer-street, S.W.1. Sat., April 2, 6.30 p.m.

North East Coast Institution of Engineers and Shipbuilders

NEWCASTLE-UPON-TYNE
"Some Investigations into Singing Propellers," by S. G. Lankester and W. D. Wallace. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., April 4, 6.15 p.m.

Sheffield Metallurgical Association

SHEFFIELD
"Safety in the Laboratory," by Dr. L. J. Burrage. B.I.S.R.A. Laboratories, Hoyle-street, Sheffield, 3. Tues., April 5, 7 p.m.

Society of Engineers

LONDON
"Civil Engineering Works at Castle Donington Power Station," by J. T. Edwards. Geological Society, Burlington House, Piccadilly, W.1. Mon., April 4, 5.30 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 5927.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Engineers' Guild, 78 Buckingham-gate, London, S.W.1. (ABBey 7315.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester 3. (Blackfriars 6178.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Metals, 4 Grosvenor-gardens, London, S.W.1. (SLOane 6233.)
Institute of Petroleum, Manson House, 26 Portland-place, London, W.1. (LANgham 2250.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. (SLOane 9851.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Engineering Designers, 38 Portland-place, London, W.1. (LANgham 8847.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of Railway Signal Engineers, Euston House, Eversholt-street, London, N.W.1.
Institution of the Rubber Industry, 12 Whitehall, London, S.W.1. (WHItehall 5012.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
London Association of Engineers, 5 Wimborne-grove, Watford, Hertfordshire. (Watford 6044.)
North East Coast Institution of Engineers and Shipbuilders, Bolbec Hall, Newcastle-upon-Tyne 1. (Newcastle 20289.)
Sheffield Metallurgical Association, 15 Crescent-road, Sheffield 7. (Sheffield 53674.)
Society of Engineers, 17 Victoria-street, London, S.W.1. (ABBey 7244.)